SECTION 8

FISH BIOASSESSMENT PROTOCOLS FOR USE IN STREAMS AND RIVERS[1]

8.1 Introduction

8.1.1 Two levels of fish bioassessment analyses are presented. Fish Bioassessment I constitutes a questionnaire approach where local and State fisheries experts are canvassed for existing data and information; Fish Bioassessment II consists of collecting fish at selected sites for biosurvey analyses. The data collected in Fish Bioassessment II is used in the Index of Biotic Integrity (IBI) (Karr et al., 1986) and the Index of well-being (Iwb) or composite index (Gammon, 1976, 1980; Gammon et al., 1981, 1988). This section provides an overview of the IBI and Iwb and their conceptual foundations. Effective use of the Fish Bioassessment II requires information presented in Angemeier and Karr (1986), Karr et al. (1986) and Gammon (1980). Sample field and data sheets are presented for guidance.

8.1.2 Pilot studies based on use of the fish biosurvey (Fish Bioassessment II) have been published. An overview of two of these studies is presented in Plafkin et al. (1989). Other studies by Bramblett and Fausch (1991), Hughes, and Gammon (1987), Ohio EPA (1987b, 1987c. 1990a), Plafkin et al. (1989), Schrader (1989), Simon (1990, 1991), Steedman (1988), Yoder et al. (1981), and those states or agencies cited in Subsection 8.15 have applied the IBI and Iwb, or the modified Iwb, to assess the effects of impacts in habitats of different regions of North America.

8.1.3 Use of Fish in Biosurveys

8.1.3.1 The bioassessment techniques presented here focus on the evaluation of water quality, habitat, and fish community parameters. The fish survey protocols were based largely on Karr's IBI (Karr, 1981; Karr et al., 1986; Miller et al., 1988b), which uses fish community structure to evaluate water quality. The integration of functional and structural compositional metrics, which forms the basis for the IBI is a common element to the fish bioassessment approach.

8.1.3.2 Advantage of Using Fish

8.1.3.2.1 Fish are good indicators of long-term (several years) effects and broad habitat conditions because they are relatively long-lived and contain mobile elements (Karr et al., 1986). In addition, many species are relatively sedentary in summer (Gerking, 1959).

8.1.3.2.2 Fish communities generally include a range of species that are representation of a variety of trophic levels (omnivores, herbivores, insectivores, planktivores, piscivores). They tend to integrate effects of

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[1]Adapted from Plafkin et al. (1989).

lower trophic levels; thus, the fish community structure can present an integrated picture of the environmental health of a stream or river.

8.1.3.2.3 Fish are at the top of the aquatic food chain and are consumed by humans, making them important target assemblage for assessing contamination and habitat alteration.

8.1.3.2.4 Fish are relatively easy to collect and identify to the species level. Most specimens can be sorted and identified in the field and released unharmed.

8.1.3.2.5 Environmental requirements of common fish are comparatively well known.

8.1.3.2.6 Life history information is extensive for most species.

8.1.3.2.7 Information on fish distribution is commonly available.

8.1.3.2.8 Aquatic life uses (water quality standards) are typically characterized in terms of fisheries (coldwater, coolwater, warmwater, sport, forage, commercial).

8.1.3.2.9 Monitoring fish communities provides direct evaluation of "fishability", which emphasizes the importance of fish to anglers and commercial fishermen.

8.1.3.2.10 Fish account for nearly half of the endangered vertebrate species and subspecies in the United States.

8.1.4 Fish Community Consideration

8.1.4.1 Seasonal changes in the relative abundance of the fish community primarily occur during reproductive periods and (for some species) the spring and fall migratory periods. However, because larval fish sampling is not recommended in this method, reproductive period changes in relative abundance are not of primary importance.

8.1.4.2 Generally, the preferred sampling season is mid to late summer and early fall, when stream and riverflows are moderate to low, and less variable than during other seasons. Although some fish species are capable of extensive migration, fish populations and individual fish tend to remain in the same area during summer (Funk, 1957; Gerking, 1959; Cairns and Kaesler, 1971). The Ohio EPA (Rankin, 1987, personal communication) confirmed that few species or individuals of a species in perennial streams migrate long distances. Hill and Grossman (1987) found that the three dominant fish species in a North Carolina stream had home ranges of 13 to 19 m over a period of 18 months. Ross et al. (1985) and Matthews (1986) found that stream fish assemblages were stable and persistent for 10 years, recovering rapidly from droughts and floods indicating that large population fluctuations are unlikely to occur in response to purely natural environmental phenomena. However, comparison of data collected during different seasons is discouraged, as is data collected during or immediately after major flow changes.

8.1.5 Station Siting

8.1.5.1 Fish Bioassessment II includes the collection of biological samples to assess the biotic integrity of a given site. To meaningfully evaluate biological condition, sampling locations must be carefully selected to ensure generally comparable habitats at each station. Unless comparable physical habitat is sampled at all stations, community differences attributable to a degraded habitat will be difficult to separate from those resulting from water quality degradation. The availability of habitats at each sampling location can be established during preliminary reconnaissance. In situations where evaluations at several stations on a waterbody will be compared, the station with the greatest habitat constraints (in terms of productive habitat availability) should be noted. The station with the least number of productive habitats available will often determine the type of habitat to be sampled at all stations of comparison.

8.1.5.2 Locally modified sites, such as small impoundments and bridge areas, should be avoided unless data are needed to assess the effects of these structures. Sampling near the mouths of tributaries entering large waterbodies should also be avoided since these areas will have habitat more typical of the larger waterbody (Karr et al., 1986).

8.1.5.3 Although the specific bioassessment objective is an important consideration in locating sampling stations, all assessments require a site-specific control station or reference data from comparable sites within the same region. A site-specific reference area or site (Ohio EPA, 1990b, 1991) is generally thought to be most representative of "best attainable" conditions for a particular waterbody. However, regional reference conditions may also be desirable to allow evaluation on a larger geographic scale. Where feasible, effects should be bracketed by establishing a series or network of sampling stations at points of increasing distance from the impact source(s). These stations will provide a basis for delineating impact and recovery zones (these zones are not "reference stations").

8.1.5.4 Omernik (1987) and Omernik and Gallant (1988) have provided an ecoregional framework for interpreting spatial patterns in state and national data. The geographical framework is based on regional patterns in land-surface form, soil types, potential natural vegetation, and land use, which vary across the county. The use of ecoregions or similar approaches can provide a geographic framework for more efficient management of aquatic ecosystems and their components (Hughes, 1985; Hughes et al., 1982, 1986, 1987; Hughes and Larsen, 1988; Larsen et al., 1988). One method for evaluating fish community composition is utilizing the ecoregion approach. Another approach includes regional reference sites or control sites. The application of the ecoregion versus the reference site approaches have been documented (e.g., Larson et al., 1986; Ohio EPA, 1987b, 1989, 1990b; Rohm et al, 1987; Whittier et al., 1988), but further studies are still needed to determine the effectiveness of these approaches for other regions of North America. In addition, investigations will be required to (1) delineate areas that differ significantly in their innate biological potential, (2) locate reference sites within each ecoregion that fully support aquatic life uses; and (3) develop biological criteria (e.g., define optimal values for the metrics recommended) using data generated with the fish bioassessment II protocol.

8.1.6 Importance of Habitat Assessment

8.1.6.1 The procedures for assessing habitat quality presented in this Section are an integral component of the final evaluation of impairment. The matrix used to assess habitat quality is based on key physical characteristics of the waterbody and the surrounding land. All of the habitat parameters evaluated are related to overall aquatic life use and are potential factors which could contribute to a limitation of the aquatic biota in the waterbody.

8.1.6.2 Habitat, as affected by instream and surrounding topographical features, can be a major determinant to aquatic community potential. Both the quality and quantity of available habitat will affect the structure and composition of resident biological communities. The effects of such pertubations can be minimized by sampling similar habitats at all stations being compared. However, when all stations are not physically comparable, habitat characterization is particularly important for proper interpretation of biosurvey results.

8.1.6.3 Where habitat quality is similar, detected impacts can be attributed to water quality factors. However, where habitat quality differs substantially from reference conditions, the question of use attainability and physical habitat alteration/restoration must be addressed. Final conclusions regarding the presence and degree of biological impairment should thus include an evaluation of habitat quality to determine the extent that habitat may be a limiting factor. The habitat characterization matrix included in the fish bioasessment II methods provides an effective means of evaluating and documenting habitat quality at each biosurvey station.

8.1.7 Fish Sampling Methodology (See, Section 4, Sample Collection for Analysis of the Structure and Function of Fish Communities.)

8.1.7.1 Use of Electrofishing, Seining, and Rotenoning

8.1.7.1.1 Although various types of gear are routinely used to sample fish, electrofishers, seines, and rotenone are the most commonly used for collection in freshwater habitats. As detailed earlier each method has advantages and disadvantages (Nielsen and Johnson, 1983; Hendricks et al., 1980). However, electrofishing is recommended for most fish field surveys because of its greater applicability and efficiency. Local conditions may require consideration of seining and/or the use of rotenone as optional collection methods. Advantages and disadvantages of each approach are presented below.

8.1.7.2 Advantages of Electrofishing

1. Electrofishing allows greater standardization of catch per unit of effort.

2. Electrofishing requires less time and manpower than some sampling methods (e.g., use of ichthyocides, like rotenone) (Hendricks et al., 1980).

3. Electrofishing is less selective than seining (although it is selective towards size and species) (Hendricks et al., 1980) (See disadvantage number 2).

4. If properly used, adverse effects on fish are minimized.

5. Electrofishing is appropriate in a variety of habitats.

8.1.7.3 Disadvantages of Electrofishing

1. Sampling efficiency is affected by turbidity, conductivity, aquatic vegetation, depth, etc.

2. Although less selective than seining, electrofishing also is size and species selective. Effects of electrofishing increase with body size. Species specific behavioral and anatomical differences also determine vulnerability to electroshocking (Reynolds, 1983).

3. Electrofishing is a hazardous operation that can injure field personnel if proper safety procedures are ignored.

8.1.7.4 Advantages of Seining

1. Seines are relatively inexpensive.

2. Seines are lightweight and are easily transported and stored.

3. Seine repair and maintenance are minimal and can be accomplished onsite.

4. Seine use is not restricted by water quality parameters.

5. Effects on the fish population are minimal because fish are collected alive and are generally unharmed.

8.1.7.5 Disadvantages of Seining

1. Previous experience and skill, knowledge of fish habitats and behavior, and sampling effort are probably more important in seining than in the use of any other approaches (Hendricks et al., 1980).

2. Seining sample effort and results are more variable than sampling with electrofishing or rotenoning.

3. Seine use is generally restricted to slower water with smooth bottoms, and is most effective in small streams or pools without litter cover or debris.

4. Standardization of unit of effort to ensure data comparability is difficult.

8.1.7.6 Advantages of Using Rotenone

1. The effective use of rotenone is independent of habitat complexity.

2. Rotenoning provides greater standardization of unit of effort than seining.

3. Rotenoning has the potential, if used effectively, to provide more complete censuring of the fish population than seining or electrofishing.

8.1.7.7 Disadvantages of Using Rotenone

1. Use of rotenone is prohibited in many states.

2. Application and detoxification can be time and manpower intensive.

3. Effective use of rotenone is affected by temperature, light, dissolved oxygen, alkalinity, and turbidity (Hendricks et al., 1980).

4. Rotenoning typically has a high environmental impact; concentration miscalculations can produce substantial fish kills downstream of the study site.

8.2 Sampling Representative Habitat

8.2.1 The sampling approach advocated in the Fish Bioassessment II optimizes the conservation of manpower and resources by sampling areas of representative habitat. The fish survey provides a representative estimate of the fish community at all habitats within a site, and a realistic sample of fish likely to be encountered in the water body. When sampling large streams, rivers, or waterbodies with complex habitats, a complete inventory of the entire reach is not necessary for the level of assessment used in the Fish Bioassessment II. The sampling area should be representative of the reach, incorporating riffles, runs, and pools if these habitats are typical of the stream in question. Although a sampling site with two riffles, two runs, and two pools is preferable, at least one of each habitat type should be evaluated. Mid-channel and wetland areas of large rivers, which are difficult to sample effectively, may be avoided. Sampling effort may be concentrated in near-shore habitats where most species will be collected. In doing so, some deep water or wetland species may be under-sampled, however, the data should be adequate for the objective of the Fish Bioassessment II method.

8.3 Fish Sample Processing and Enumeration

8.3.1 To ensure data comparability for assessing biological condition with the Fish Bioassessment II, sample processing and species enumeration must be standardized.

8.3.2 Processing of the fish biosurvey sample includes identification of all individuals to species, weighing (if the Index of well-being (Iwb) or biomass data are desired), and recording the incidence of external anomalies. It is recommended that each fish be identified and counted. Subsamples of abundant species may be weighed if live wells are unavailable. This is especially important for warmwater sites, where handling mortality is highly probable.

The data from the counted and weighed subsample is extrapolated for the total. Ohio EPA (1987a) has reported that subsampling reduced potential error and made the extra time required for individual weighing insignificant. Procedural details for subsampling are presented in Ohio EPA, 1987c. Determination of species trophic status is also necessary for some IBI metrics. It should also be standard practice to collect fish Total Length (TL) and Standard Length (SL) information.

8.4 Fish Environmental Tolerance Characterizations

8.4.1 Use of the Index of Biological Integrity (IBI) in the Fish Bioassessment II requires classification of fish species in terms of environmental tolerance. Responses of individual species to pollution will vary regionally and in accordance with the type of pollutant. The tolerance characterizations of selected midwestern and northwestern fish species are presented in Table 1. Effective use of the tolerance characterization approach requires an appropriate regional tolerance characterization system. Regional modification or substitutions may be based upon regional fish references, historical distribution records, objective assessment of a large statewide database, and toxicological test data. Application of the IBI approach in the southeastern and southwestern United States, and its widespread use by water resource agencies may result in additional modifications. Past modifications have been reported (Subsection 8.8, Miller et al., 1988a) without changing the IBI's basic theoretical foundations.

8.5 Fish Biosurvey and Data Analysis

8.5.1 Bioassessment Technique

8.5.1.1 A biological assessment involves an integrated analysis of the functional and structural components of the aquatic communities. These functional and structural components are evaluated through the use of 12 metrics based on fish. The range of pollution sensitivity exhibited by each metric differs among metrics (Figure 1); some are sensitive across a broad range of biological conditions, others only to part of the range.

8.5.1.2 The 12 IBI metrics used in the Fish Bioassessment II method are based on fish representing different sensitivities (Figure 2). For example, municipal effluents typically affect total abundance and trophic structure (Karr et al., 1986). Unusually low total abundance generally indicates a toxicant effect. However, some nutrient-deficient environments support a limited number of individuals or individual species, and an increase in abundance may indicate organic enrichment. Bottom dwelling species (e.g., darters, sculpins) that depend upon benthic habitats for feeding and reproduction are particularly sensitive to the effects of siltation and benthic oxygen depletion (Kuehne and Barbour, 1983; Ohio EPA, 1987b) and are good indicators of habitat degradation.

8.5.1.3 For the fish biosurvey and habitat assessment, scores are assigned to each metric or parameter based on a decision matrix. In the case of habitat assessment, evaluation of the quality of the parameter is based on visual observation. The score assigned to each habitat parameter is a compilation of

TABLE 1. TOLERANCE DESIGNATIONS, TROPHIC STATUS, AND NORTH AMERICAN ENDEMICITY OF SELECTED FISH SPECIES[a]

	Trophic Level	Tolerance	Origin
WILLAMETTE SPECIES[1]			
Salmonidae			
Chinook salmon	piscivore	intolerant	native
Cutthroat trout	insectivore	intolerant	native
Mountain whitefish	insectivore	intolerant	native
Rainbow trout	insectivore	intolerant	native
Cyprinidae			
Chiselmouth	herbivore	intermediate	native
Common carp	omnivore	tolerant	exotic
Goldfish	omnivore	tolerant	exotic
Leopard dace	insectivore	intermediate	native
Longnose dace	insectivore	intermediate	native
Northern squawfish	piscivore	tolerant	native
Peamouth	insectivore	intermediate	native
Redside shiner	insectivore	intermediate	native
Speckled dace	insectivore	intermediate	native
Catostomidae			
Largescale sucker	omnivore	tolerant	native
Mountain sucker	herbivore	intermediate	native
Ictaluridae			
Brown bullhead	insectivore	tolerant	introduced
Yellow bullhead	insectivore	tolerant	introduced
Percopsidae			
Sand roller	insectivore	intermediate	native
Gasterosteidae			
Threespine stickleback	insectivore	intermediate	native
Centrarchidae			
Bluegill	insectivore	tolerant	introduced
Largemouth bass	piscivore	tolerant	introduced
Smallmouth bass	piscivore	intermediate	introduced
White crappie	insectivore	intermediate	native
Percidae			
Yellow perch	insectivore	intermediate	native

[a]Not necessarily the final designations: designations may vary for different regions.
[1]Classifications for the Willamette River, Oregon were derived from Wydoski and Whitney (1979). Moyle (1976), Scott and Crossman (1973), Simpson and Wallace (1982), Dimick and Merryfield (1945), and Bond (1988, personal communication.)
[2]Classifications for midwestern fishes were taken from Karr et al. (1986) and Ohio EPA (1987b).

Note: The information in this table is on going research and needs further standardization.

TABLE 1. TOLERANCE DESIGNATIONS, TROPHIC STATUS, AND NORTH AMERICAN ENDEMICITY OF SELECTED FISH SPECIES (CONTINUED)

	Trophic Level	Tolerance	Origin
Cottidae			
Paiute sculpin	insectivore	intolerant	native
Prickly sculpin	insectivore	intermediate	native
Reticulate sculpin	insectivore	tolerant	native
Torrent sculpin	insectivore	intolerant	native
MIDWEST SPECIES[2]			
Petromyzontidae			
Silver lamprey	piscivore	intermediate	native
Northern brook lamprey	filterer	intolerant	native
Mountain brook lamprey	filterer	intolerant	native
Ohio lamprey	piscivore	intolerant	native
Least brook lamprey	filterer	intermediate	native
Sea lamprey	piscivore	intermediate	exotic
Polyodontidae			
Paddlefish	filterer	intolerant	native
Acipenseridae			
Lake sturgeon	invertivore	intermediate	native
Shovelnose sturgeon	invertivore	intermediate	native
Lepisosteidae			
Alligator gar	piscivore	intermediate	native
Shortnose gar	piscivore	intermediate	native
Spotted gar	piscivore	intermediate	native
Longnose gar	piscivore	intermediate	native
Amiidae			
Bowfin	piscivore	intermediate	native
Hiodontidae			
Goldeye	insectivore	intolerant	native
Mooneye	insectivore	intolerant	native
Clupeidae			
Skipjack herring	piscivore	intermediate	native
Alewife	invertivore	intermediate	exotic
Gizzard shad	omnivore	intermediate	native
Threadfish shad	omnivore	intermediate	native
Salmonidae			
Brown trout	insectivore	intermediate	exotic
Rainbow trout	insectivore	intermediate	exotic
Brook trout	insectivore	intermediate	native
Lake trout	piscivore	intermediate	native
Coho salmon	piscivore	intermediate	exotic
Chinook salmon	piscivore	intermediate	exotic
Lake herring	piscivore	intermediate	native
Lake whitefish	piscivore	intermediate	native
Osmeridae			
Rainbow smelt	invertivore	intermediate	introduced

TABLE 1. TOLERANCE DESIGNATIONS, TROPHIC STATUS, AND NORTH AMERICAN ENDEMICITY OF SELECTED FISH SPECIES (CONTINUED)

	Trophic Level	Tolerance	Origin
Umbridae			
Central mudminnow	insectivore	tolerant	native
Esocidae			
Grass pickerel	piscivore	intermediate	native
Chain pickerel	piscivore	intermediate	native
Northern pike	piscivore	intermediate	native
Muskellunge	piscivore	intermediate	native
Cyprinidae			
Common carp	omnivore	tolerant	exotic
Goldfish	omnivore	tolerant	exotic
Grass carp	herbivore	intermediate	exotic
Golden shiner	omnivore	tolerant	native
Hornyhead chub	insectivore	intolerant	native
River chub	insectivore	intolerant	native
Silver chub	insectivore	intermediate	native
Bigeye chub	insectivore	intolerant	native
Streamline chub	insectivore	intolerant	native
Gravel chub	insectivore	intermediate	native
Speckled chub	insectivore	intolerant	native
Blacknose dace	generalist	tolerant	native
Longnose dace	insectivore	intolerant	native
Creek chub	generalist	tolerant	native
Tonguetied minnow	insectivore	intolerant	native
Suckermouth minnow	insectivore	intermediate	native
Southern redbelly dace	herbivore	intermediate	native
Redside dace	insectivore	intolerant	native
Pugnose minnow	insectivore	intolerant	native
Emerald shiner	insectivore	intermediate	native
Silver shiner	insectivore	intolerant	native
Roseyface shiner	insectivore	intolerant	native
Redfin shiner	insectivore	intermediate	native
Rosefin shiner	insectivore	intermediate	native
Striped shiner	insectivore	intermediate	native
Common shiner	insectivore	intermediate	native
River shiner	insectivore	intermediate	native
Spottail shiner	insectivore	intermediate	native
Blackchin shiner	insectivore	intolerant	native
Bigeye shiner	insectivore	intolerant	native
Steelcolor shiner	insectivore	intermediate	native
Spotfish shiner	insectivore	intermediate	native
Bigmouth shiner	insectivore	intermediate	native
Sand shiner	insectivore	intermediate	native
Mimic shiner	insectivore	intolerant	native
Ghost shiner	insectivore	intermediate	native
Blacknose shiner	insectivore	intolerant	native
Pugnose shiner	insectivore	intolerant	native

TABLE 1. TOLERANCE DESIGNATIONS, TROPHIC STATUS, AND NORTH AMERICAN ENDEMICITY OF SELECTED FISH SPECIES (CONTINUED)

	Trophic Level	Tolerance	Origin
Cyprinidae			
Mississippi silvery minnow	herbivore	intermediate	native
Bullhead minnow	omnivore	intermediate	native
Bluntnose minnow	omnivore	tolerant	native
Fathead minnow	omnivore	tolerant	native
Central stoneroller	herbivore	intolerant	native
Popeye shiner	insectivore	intolerant	native
Silverjaw minnow	insectivore	intermediate	native
Central silvery minnow	herbivore	intolerant	native
Red shiner	omnivore	intermediate	native
Brassy minnow	omnivore	intermediate	native
Catostomidae			
Blue sucker	insectivore	intolerant	native
Bigmouth buffalo	insectivore	intermediate	native
Black buffalo	insectivore	intermediate	native
Smallmouth buffalo	insectivore	intermediate	native
Quilback	omnivore	intermediate	native
River carpsucker	omnivore	intermediate	native
Highfin carpsucker	omnivore	intermediate	native
Silver redhorse	insectivore	intermediate	native
Black redhorse	insectivore	intolerant	native
Golden redhorse	insectivore	intermediate	native
Shorthead redhorse	insectivore	intermediate	native
Greater redhorse	insectivore	intolerant	native
River redhorse	insectivore	intolerant	native
Harelip sucker	invertivore	intolerant	native
Northern hog sucker	insectivore	intolerant	native
White sucker	omnivore	tolerant	native
Longnose sucker	insectivore	intermediate	native
Spotted sucker	insectivore	intermediate	native
Lake chubsucker	insectivore	intermediate	native
Creek chubsucker	insectivore	intermediate	native
Ictaluridae			
Blue catfish	piscivore	intermediate	native
Channel catfish	generalist	intermediate	native
White catfish	insectivore	intermediate	native
Yellow bullhead	insectivore	tolerant	native
Brown bullhead	insectivore	tolerant	native
Black bullhead	insectivore	intermediate	native
Flathead catfish	piscivore	intermediate	native
Stonecat	insectivore	intolerant	native
Mountain madtom	insectivore	intolerant	native
Slender madtom	insectivore	intolerant	native
Freckled madtom	insectivore	intermediate	native
Northern madtom	insectivore	intolerant	native
Scioto madtom	insectivore	intolerant	native

TABLE 1. TOLERANCE DESIGNATIONS, TROPHIC STATUS, AND NORTH AMERICAN ENDEMICITY OF SELECTED FISH SPECIES (CONTINUED)

	Trophic Level	Tolerance	Origin
Ictaluridae			
Brindled madtom	insectivore	intolerant	native
Tadpole madtom	insectivore	intermediate	native
Anguillidae			
American eel	piscivore	intermediate	native
Fundulidae			
Western banded killfish	insectivore	intolerant	native
Eastern banded killfish	insectivore	tolerant	native
Blackstrip topminnow	insectivore	intermediate	native
Poeciliidae			
Mosquitofish	insectivore	intermediate	exotic
Gadidae			
Burbot	piscivore	intermediate	native
Moronidae			
Trout-perch	insectivore	intermediate	native
Aphredoderidae			
Pirate perch	insectivore	intermediate	native
Atherinidae			
Brook silverside	insectivore	intermediate	native
Percichthyidae			
White bass	piscivore	intermediate	exotic
Stripped bass	piscivore	intermediate	exotic
White perch	piscivore	intermediate	exotic
Yellow bass	piscivore	intermediate	exotic
Centrarchidae			
White crappie	invertivore	intermediate	native
Black crappie	invertivore	intermediate	native
Rock bass	piscivore	intermediate	native
Smallmouth bass	piscivore	intermediate	native
Spotted bass	piscivore	intermediate	native
Largemouth bass	piscivore	intermediate	native
Warmouth	invertivore	intermediate	native
Green sunfish	insectivore	tolerant	native
Bluegill	insectivore	intermediate	native
Orangespotted sunfish	insectivore	intermediate	native
Longear sunfish	insectivore	intolerant	native
Redear sunfish	insectivore	intermediate	native
Pumpkinseed	insectivore	intermediate	native
Percidae			
Sauger	piscivore	intermediate	native
Walleye	piscivore	intermediate	native
Yellow perch	piscivore	intermediate	native
Dusky darter	insectivore	intermediate	native
Blackside darter	insectivore	intermediate	native
Longhead darter	insectivore	intolerant	native

TABLE 1. TOLERANCE DESIGNATIONS, TROPHIC STATUS, AND NORTH AMERICAN ENDEMICITY OF SELECTED FISH SPECIES (CONTINUED)

	Trophic Level	Tolerance	Origin
Percidae			
Slenderhead darter	insectivore	intolerant	native
River darter	insectivore	intermediate	native
Channel darter	insectivore	intolerant	native
Gilt darter	insectivore	intolerant	native
Logperch	insectivore	intermediate	native
Crystal darter	insectivore	intolerant	native
Eastern sand darter	insectivore	intolerant	native
Western sand darter	insectivore	intolerant	native
Johnny darter	insectivore	intermediate	native
Greenside darter	insectivore	intermediate	native
Banded darter	insectivore	intolerant	native
Variegate darter	insectivore	intolerant	native
Spotted darter	insectivore	intolerant	native
Bluebreast darter	insectivore	intolerant	native
Tippecanoe darter	insectivore	intolerant	native
Iowa darter	insectivore	intermediate	native
Rainbow darter	insectivore	intermediate	native
Orangethroat darter	insectivore	intermediate	native
Fantail darter	insectivore	intermediate	native
Least darter	insectivore	intermediate	native
Slough darter	insectivore	intermediate	native
Sciaendiae			
Freshwater drum	invertivore	intermediate	native
Cottidae			
Spoonhead sculpin	insectivore	intermediate	native
Mottled sculpin	insectivore	intermediate	native
Slimy sculpin	insectivore	intermediate	native
Deepwater sculpin	insectivore	intermediate	native
Gasterosteidae			
Brook stickleback	insectivore	intermediate	native

Select a Site

Identify Regional Fish Fauna

Assign Species to Trophic, Tolerance, and Origin Guilds

Assess Available Data for Metric Suitability and Stream Size Patterns

Develop Scoring Criteria from Reference Sites

Quantitatively Sample Fish

List Abundances of Species, Hybrids, and Anomalies

Calculate and Score Metric Values

METRIC SCORES (IBI)

Metric	Scoring Criteria[a] 5	3	1
1. Number of native fish species	>67%	33–67%	<33%
2. Number of darter or benthic species	>67%	33–67%	<33%
3. Number of sunfish or pool species	>67%	33–67%	<33%
4. Number of sucker or long-lived species	>67%	33–67%	<33%
5. Number of intolerant species	>67%	33–67%	<33%
6. Proportion of green sunfish or tolerant individuals	<10%	10–25%	>25%
7. Proportion omnivorous individuals	<20%	20–45%	>45%
8. Proportion insectivores	>45%	20–45%	<20%
9. Proportion top carnivores	>5%	1–5%	<1%
10. Total number of individuals	>67%	33–67%	<33%
11. Proportion hybrids or exotics	0%	0–1%	>1%
12. Proportion with disease/anomalies	<1%	1–5%	>5%

Note: Not Universal Criteria

[a]Metrics 1–5 are scored relative to the maximum species richness line. Metric 10 is drawn from reference site data.

INDEX SCORE INTERPRETATION[a]

IBI	Integrity Class	Characteristics
58–60	Excellent	Comparable to pristine conditions, exceptional assemblage of species
48–52	Good	Decreased species richness, intolerant species in particular; sensitive species present
40–44	Fair	Intolerant and sensitive species absent; skewed trophic structure
28–34	Poor	Top carnivores and many expected species absent or rare; omnivores and tolerant species dominant
12–22	Very Poor	Few species and individuals present; tolerant species dominant; diseased fish frequent

[a]From Karr et al. 1986; Ohio EPA 1987.

Recommendations

Figure 1. Flowchart of biosurvey approach for Fish Bioassessment II.

a range of scores and is weighted in terms of its contribution to the total habitat quality. The scores assigned to the fish metrics are based on computed values of the metrics and a station comparison, wherein the regional or stream reference station serves as the highest attainment criterion or score for the area. Comparison of the total score computed for the metrics orparameters with that of the reference station provides a judgment as to impairment of biological condition.

8.5.1.4 The condition of the aquatic community needs to be evaluated and interpreted within the context of habitat quality in order to determine effects and likely causal factors. A poor habitat in terms of riparian vegetation, bank stability, stream substrate, etc., would not be conducive to supporting a well-developed community structure. The attainment of a higher quality biological condition may be prohibited by the constraints of habitat quality.

8.6 Fish Bioassessment I

8.6.1 The intent of the Fish Bioassessment I is to consist of a questionnaire, to serve as a screening tool, and to maximize the use of existing knowledge of fish communities. **Note:** The Fish Bioassessment I method is not an option for a minimum state bioassessment program. The

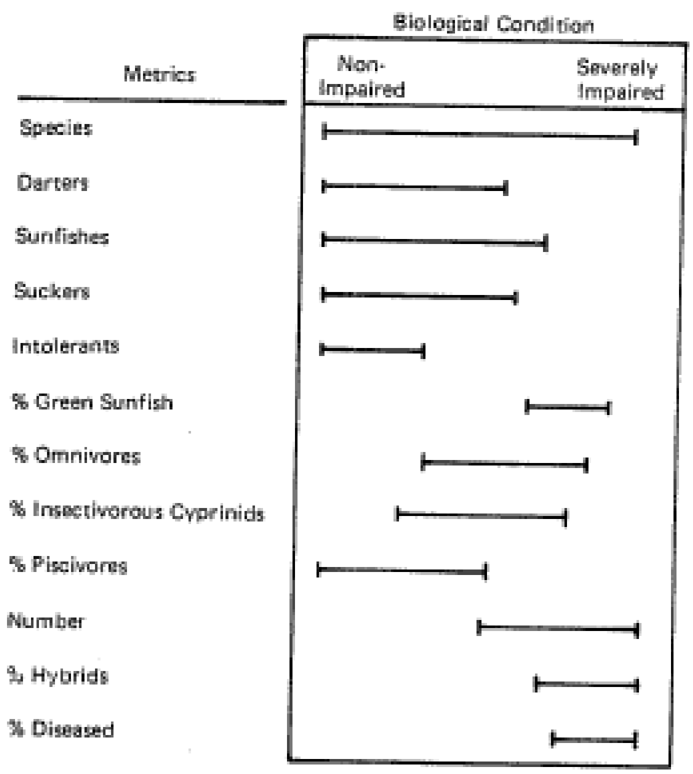

Figure 2. Range of sensitivities of biosurvey for Fish Bioassessment II metrics in assessing biological condition (from Karr et al., 1986).

questionnaire polls State fish biologists and university ichthyologists believed knowledgeable about the fish assemblages in stream reaches of concern. The questionnaire (Figure 3) is modeled after one used in a successful national survey of 1,300 river reaches or segments (Judy et al., 1984). Unlike field surveys, questionnaires can provide information about tainting or fish tissue contamination and historical trends and conditions. Disadvantages of the questionnaire approach include inaccuracy caused by hasty responses, a desire to report conditions as better or worse than they are, and insufficient knowledge. The questionnaire provides a qualitative assessment of a large number of water bodies quickly and inexpensively. Its quality depends on the survey design (the number and location of waterbodies), the questions presented, and the knowledge and cooperation of the respondents.

8.6.2 This section provides guidance on the design and content of the questionnaire survey. Judy et al. (1984) found that State fish and game agencies have a vested interest in assuring the quality of the data, and they generally provide reliable information.

8.6.3 Design of Fish Assemblage Questionnaire Survey

8.6.3.1 Selection of stream reaches requires considerable forethought. If the survey program is statewide or regional in scope, a regional framework is advisable. Regional reference reaches can be selected to serve as benchmarks for comparisons (Hughes et al., 1986). These sites should be characteristic of the water body types and sizes in the region and should be minimally impacted. The definition of minimal impact varies from region to region, but includes those waters that are generally free of point sources, channel modification, and diversions, and have diverse habitats, complex bottom substrate, considerable instream cover, and a wide buffer or natural riparian vegetation.

8.6.3.2 Remaining sites should also be selected carefully. If the questionnaire focuses on larger streams, a 1:1,000,000 scale topographic map should be used for stream reach selection. Reaches of small streams should be selected from the largest scale map possible; reaches selected from 1:250,000 versus 1:24,000 scale topographic maps may omit as much as 10 percent of the permanent streams in humid, densely forested areas. Small, medium, and large streams should be selected based on their importance in the region.

8.6.3.3 The potential respondent (or the agency chief if a number of agency staff are to be questioned) should be contacted initially by telephone to identify appropriate respondents. To ensure maximum response, the questionnaire should be sent at times other than the field season and the beginning and end of the a fiscal year or other seasonally busy time. The questionnaire should be accompanied by a personalized cover letter written on official stationary, and closed by an official title below the signature. A stamped, self-addressed return envelope increases the response rate. Materials mailed first or priority class are effective; special delivery and certified letters are justified in follow-up mailings. Telephone contact is advisable after three follow-up notes.

FISH ASSEMBLAGE QUESTIONNAIRE

INTRODUCTION

This questionnaire is part of an effort to assess the biological health or integrity of the flowing waters of this state. Our principle focus is on the biotic health of the designated waterbody as indicated by its fish community. You were selected to participate in the study because of your expertise in fish biology and your knowledge of the waterbody identified in this questionnaire.

Using the scale below, please circle the rank (at left) corresponding to the explanation (at right) that best describes your impression of the condition of the waterbody. Please complete all statements. If you feel that you cannot complete the questionnaire, check here [ ] and return it. If you are unable to complete the questionnaire but are aware of someone who is familiar with the waterbody, please give this person's name, address, and telephone number in the space provided below.

____

____

____

Waterbody code __________________________

Waterbody name __________________________

Waterbody location (also see map)

State __________ County ____________ Long/Lat_______

Ecoregion _______________

Waterbody size

Stream (<1 cfs, 1-10 cfs, >10 cfs)

(Answer questions 1-4 using the scale below.)

5 Species composition, age classes, and trophic structure comparable to non (or minimally) impacted sites of similar waterbody size in that ecoregion.

4 Species richness somewhat reduced by loss of some intolerant species; young of the year of top carnivores rare; less than optimal abundances, age distributions, and trophic structure for waterbody size and ecoregion.

3 Intolerant species absent, considerably fewer species and individuals than expected for that waterbody size and ecoregion, older age classes of top carnivores rare, trophic structure skewed toward omnivory.

Figure 3. Fish assemblage questionnaire for use with Fish Bioassessment I.

2 Dominated by highly tolerant species, omnivores, and habitat generalists; top carnivores rare or absent; older age classes of all but tolerant species rare; diseased fish and anomalies relatively common for that waterbody size and ecoregion.

1 Few individuals and species present, mostly tolerant species and small individuals, diseased fish and anomalies abundant compared to other similar-sized waterbodies in the ecoregion.

0 No fish

(Circle one number using the scale above.)

1. Rank the current conditions of the reach

   5 4 3 2 1 0

2. Rank the conditions of the reach 10 years ago

   5 4 3 2 1 0

3. Given present trends, how will the reach rank 10 years from now?

   5 4 3 2 1 0

4. If the major human-caused limiting factors were eliminated, how would the reach rank 10 years from now?

   5 4 3 2 1 0

(Complete each subsection by circling the single most appropriate limiting factor and probable cause.)

<u>Subsection I</u>--Water Quality

Limiting factor

5 Temperature too high
6 Temperature too low
7 Turbidity
8 Salinity
9 Dissolved oxygen
10 Gas supersaturation
11 pH too acidic
12 pH too basic
13 Nutrient deficiency
14 Nutrient surplus
15 Toxic substances
16 Other (specify below)

____

17 Not limiting

Probable cause

18 Primarily upstream
19 Within reach
20 Point source discharge
21 Industrial
22 Municipal
23 Combined sewer
24 Mining
25 Dam release
26 Nonpoint source discharge
27 Individual sewage
28 Urban runoff
29 Landfill leachate
30 Construction
31 Agriculture
32 Feedlot
33 Grazing
34 Silviculture
35 Mining
36 Natural
37 Unknown
38 Other (specify below)

____

Figure 3. Fish assemblage questionnaire for use with Fish Bioassessment I (Continued).

Subsection 2--Water Quantity

Limiting factor	Probable source
39 Below optimum flows	45 Dam
40 Above optimum flows	46 Diversion
41 Loss of flushing flows	47 Watershed conversion
42 Excessive flow fluctuation	48 Agriculture
43 Other (specify below) ______	49 Silviculture
44 Not limiting	50 Grazing
	51 Urbanization
	52 Mining
	53 Natural
	54 Unknown
	55 Other (specify below) ______

Subsection 3--Habitat Structure

Limiting factor	Probable cause
56 Excessive siltation	64 Agriculture
57 Insufficient pools	65 Silviculture
58 Insufficient riffles	66 Mining
59 Insufficient shallows	67 Grazing
60 Insufficient concealment	68 Dam
61 Insufficient reproductive habitat	69 Diversion
62 Other (specify below) ______	70 Channelization
63 Not limiting	71 Snagging
	72 Other channel modifications
	73 Natural
	74 Unknown
	75 Other (specify below) ______

Subsection 4--Fish Community

Limiting factor	Probable source
76 Overharvest	84 Fishermen
77 Underharvest	85 Aquarists
78 Fish stocking	86 State agency
79 Non-native species	87 Federal agency
80 Migration barrier	88 Point source
81 Tainting	89 Nonpoint source
82 Other (specify below) ______	90 Natural
83 Not limiting	91 Unknown
	92 Other (specify below) ______

Subsection 5--Major Limiting Factor

93 Water quality
94 Water quantity
95 Habitat structure
96 Fish community
97 Other (specify) ______

Your name (please print) ______

Figure 3. Fish assemblage questionnaire for use with Fish Bioassessment I (Continued).

8.6.4 Response Analysis

8.6.4.1 Questionnaire response should provide the following information:

1. The integrity of the fish community

2. The frequency of occurrence of particular limiting factors and causes

3. The frequency of occurrence of particular fish community condition characterizations for the past, present, and future

4. The geographic patterns in these variables

5. The temporal trends in the variables

6. Effect of water body type and size on the spatial and temporal trends and the associated limiting factors

7. The likelihood of improvement and degradation

8. The major limiting factor

8.6.4.2 The questionnaire data are most effectively analyzed by using a microcomputer and an interactive data base management software (e.g., *d*Base III or Revelation). This software reduces data entry errors and facilitates the qualitative analysis of numerous variables. Results can be reported as histograms, pie graphs, or box plots. If such a system is unavailable data can be analyzed and the results plotted by hand.

8.7 Fish Bioassessment II

8.7.1 Introduction

8.7.1.1 Fish Bioassessment II involves careful, standardized field collection, species identification and enumeration, and community analyses using biological indices or quantification of the biomass and numbers of key species. The Fish Bioassessment II survey yields an objective, discrete measure of the health of the fish community that usually can be completed onsite by qualified fish biologists (difficult species identifications may require laboratory confirmation). Data provided by the Fish Bioassessment II can allow assessment to use attainment, can be used to develop biological criteria, prioritize sites for further evaluation, provide a reproducible impact assessment, and be used to monitor trends in fish community status. Fish Bioassessment II is based primarily on the Index of Biotic Integrity (IBI) by Karr (1981). A more detailed description of this approach is presented in Karr et al. (1986) and Ohio EPA (1987b). Regional modification and applications are described in Hughes and Gammon (1987), Leonard and Orth (1986), Lyons (1992), Steedman (1988), Wade and Stalcup (1987), Miller et al. (1988a), and Simon (1990, 1991).

8.7.2 Field Survey Methods

8.7.2.1 Fish Bioassessment II involves field evaluation of both physical/chemical and habitat characteristics (see Subsection 8.13, Figures 9, 10, and 11), an impairment assessment (Figure 4), and a fish community biosurvey. Because it provides critical information for evaluating the cause and source of impairment, the habitat and physical characterization are essential to Fish Bioassessment II. The approach for conducting the Fish Bioassessment II site-specific fish community analysis is based on the use of the IBI (Figure 1).

8.7.3 Sample Collection

8.7.3.1 Electrofishing, the most common technique used by agencies that monitor fish communities, and the most widely applicable approach for stream habitats, is the sampling technique recommended for use with the Fish Bioassessment II. However, pilot studies may indicate the need for different or multiple techniques and gear found in this document.

8.7.3.2 The fish community biosurvey data are designed to be representative of the fish community at all station habitats, similar to the "representative qualitative sample" proposed by Hocutt (1981). The sampling station should be representative of the reach, incorporating at least one (preferably two) riffle(s), run(s), and pool(s) if these habitats are typical of the stream in question. Sampling of most species is most effective near shore and cover (Macrophytes, boulders, snags, brush). The biosurvey is not an exhaustive inventory, but it provides a realistic sample of fishes likely to be encountered in the waterbody. Sampling procedures effective for large rivers are described in Gammon (1980), Hughes and Gammon (1987), and Ohio EPA (1987b).

8.7.3.3 Typical sampling station lengths range from 100-200 meters for small streams to 500-1000 meters in rivers, but are best determined by pilot studies. The size of the reference station should be sufficient to produce 100-1000 individuals and 80-90 percent of the species expected from a 50 percent increase in sampling distance. Sample collection is usually done during the day, but night sampling can be more effective if the water is especially clear and there is little cover (Reynolds, 1983; Sanders, 1991; Sanders, 1992). Use of block nets set (with as little wading as possible) at both ends of the reach increases sampling efficiency for large, mobile species sampled in small streams.

8.7.3.4 The community-level assessment of fish assemblages using the Fish Bioassessment II requires that all fish species (not just gamefish) be collected. This reduces the effects of stocking and fishing and acknowledges the growing public interest in nongame species. Small fish that require special gear for their effective collection may be excluded. Exclusion of young-of-the-year fish during collection can have a minor effect on IBI scores (Angermeier and Karr, 1986), but lowers sampling costs and reduces the need for laboratory identification. Karr et al., (1986) recommended exclusion of fish less than 20 mm in length. This recommendation should be considered on a regional basis and is also applicable to large fish requiring special gear for

IMPAIRMENT ASSESSMENT SHEET

1. Detection of impairment: Impairment detected (Complete Items 2-6) No impairment detected (Stop here)

2. Biological impairment indicator:

Fish

___ sensitive species reduced/absent
___ dominance of tolerant species
___ skewed trophic structure
___ abundance reduced/unusually high
___ biomass reduced/unusually high
___ hybrid or exotic abundance unusually high
___ poor size class representation
___ high incidence of anomalies

Other aquatic communities

___ Macroinvertebrates
___ Periphyton
___ Macrophytes

3. Brief description of problem: ______________________

Year and date of previous surveys: ______________________

Survey data available in: ______________________

4. Cause (indicate major cause): organic enrichment toxicants flow

sediment temperature poor habitat

other ______________________

5. Estimated areal extent of problem (m^2) and length of stream reach affected (m) where applicable: ______________________

6. Suspected source(s) of problem

___ point source
___ urban runoff
___ agricultural runoff
___ silvicultural runoff
___ livestock
___ landfill
___ mine
___ dam or diversion
___ channelization or snagging
___ natural
___ other
___ unknown

Comments: ______________________

____

Figure 4. Impairment assessment sheet for use with Fish Bioassessment II.

collection (e.g., sturgeon). The intent of the sample (as with the entire Fish Bioassessment II method) is to obtain a representative estimate of the species present, and their abundances, in a reasonable amount of effort.

8.7.3.5 Sampling effort among stations is standardized as much as possible. Regardless of the gear used, the collection method, site length (or area), and work hours expended must be comparable to allow comparison of fish community status among sites. Major habitat types (riffle, run, and pool) sampled at each site and the proportion of each habitat type sampled should also be comparable. Generally 1 to 2 hours of actual sampling time are required, but this varies considerably with the gear used and the size and complexity of the site.

8.7.3.6 Atypical conditions, such as high flow, excessive turbidity or turbulence, heavy rain, drifting leaves, or other unusual conditions that affect sampling efficiency, should be avoided.

8.7.3.7 Glare, a frequent problem, is reduced by wearing polarized glasses during sample collection.

8.7.3.8 At least four individuals (one with the electrofisher, two fish netters, and one for holding container of collected fish) are necessary for effective electrofishing, and electrofishing efficiency is increased by having experienced netters involved.

8.7.4 Sample Processing

8.7.4.1 A field collection data sheet (Figure 5) is completed for each sample. Sampling duration and area or distance sampled are recorded in order to determine level of effort. Species may be separated into adults and juveniles by size and coloration; then total numbers and weights and the incidence of external anomalies are recorded for each group. Reference specimens of each species from each site are preserved in 10 percent formaldehyde (see Section 5, Fish Specimen Processing), the jar labeled, and the collection placed with the State ichthyological museum to confirm identifications and to constitute a biological record. This is especially important for uncommon species, for species requiring laboratory identification, and for documenting new distribution records. If retained in a live well, most fish can be identified, counted, and weighted in the field by trained personnel and returned to the stream alive. In warmwater sites, where handling mortality is highly probable, each fish is identified and counted, but for abundant species, subsampling may be considered. When subsampling is employed, the subsample is extrapolated to obtain a final value. Subsampling for weight is a simple, straightforward procedure, but failure to examine all fish to determine frequency of anomalies (which may occur in about 1 percent of all specimens) can bias results. The trade off between handling mortality and data bias must be considered on a case-by-case basis. If a site is to be sampled repeatedly over several months (i.e., monitoring), the effect of sampling mortality may outweigh data bias. Holding fish in live boxes in shaded, circulating water will substantially reduce handling mortality. More information on field methods is presented in Karr et al. (1986) and Ohio EPA (1987a, 1987b, 1989).

Collection No. ______ Page ____ of ____

FISH FIELD COLLECTION DATA SHEET

State or Country __________________________ County ____________ Date ________
Locality ____
____
Water ____ Sampling duration (min.) ______
Vegetation ____
____
Bottom ____ Temp _______ Air _______
Shore ____
Distance from shore or stream width ____
Habitat complexity/quality (excellent good fair poor very poor
Sampling distance (m) _____________________ Sampling area (m^2) _______________
Depth of capture ____
Method of capture ____
Collected by ____ Date ____________
Orig. preservation __________ number of individuals____ number of anomalis*____
Weather ________________________________ Flow (flood bankfull moderate low)
Gear/crew performance ____
Comments ____

Genus/Species	Adults No. Wt.	Juveniles No. Wt.	Anomalies(*) No.

*Discoloration, deformities, eroded fins, excessive mucus, excessive external parasites, fungus, poor condition, reddening, tumors, and ulcers.

Figure 5. Fish field collection data sheet for use with Fish Bioassessment II.

8.7.5 Data Analysis Techniques

8.7.5.1 Based on observations made in the assessment of habitat, water quality, physical characteristics, and the fish biosurvey, the investigator concludes whether impairment is detected. If impairment is detected, the probable cause and source is estimated and recorded on an Impairment Assessment Sheet (Figure 4). A preliminary judgment on the presence of biological impairment is particularly important if the Fish Bioassessment I is not used prior to the Fish Bioassessment II.

8.7.5.2 Data can be analyzed using the Index of Biotic Integrity (IBI) (or individual IBI metrics), the Index of well-being (Iwb) (Gammon, 1976, 1980), and multivariate statistical techniques to determine community similarities. Detrended correspondence analysis (DCA) is a useful multivariate analysis technique for revealing regional community patterns and patterns among multiple sites (Matthews et al., 1992). It also demonstrates assemblages with compositions differing from others in the region or reach. The reader may consult Gauch (1982) and Hill (1979) for descriptions of, and software for, DCA. Data analyses and reporting, including parts of the IBI, can be computer generated. Computerization reduces the time needed to produce a report and increases staff capability to examine data patterns and implications. The Illinois EPA has developed software to assist the professional aquatic biologists in calculating IBI values in Illinois streams (Bickers et al. 1988). Use of this software outside Illinois or the particular ecoregion without modification is not recommended. However, hand calculation in the initial use of the IBI promotes understanding of the approach and provides insight into local inconsistencies.

8.7.5.3 The IBI is a broadly-based index firmly grounded in fisheries community ecology (Karr, 1981; Karr et al., 1986). The IBI incorporates zoogeographic, ecosystem, community, population, and individual perspectives. It can accommodate natural differences in the distribution and abundance of species that result from differences in waterbody size, type, and region of occurrence (Miller et al., 1988a). Use of the IBI allows national comparisons of biological integrity without the traditional bias for small coldwater streams (e.g., a salmon river in Alaska and a minnow stream in Georgia both could be rated excellent if they were comparable to the best streams expected in their respective regions).

8.7.5.4 Karr et al. (1986) provided a consistent theoretical framework for analyzing fish community data. The IBI uses 12 biological metrics to assess integrity based on the fish community's taxonomic and trophic composition and the abundance and condition of fish. Such multiple-parameter indices are necessary for making objective evaluations of complex systems. The IBI was designed to evaluate the quality of small mid-western streams but has been modified for use in many regions of the country and in large rivers (Subsection 8.8).

8.7.5.5 The metrics attempt to quantify an ichthyologist's best professional judgment of the quality of the fish community. The IBI utilizes professional judgment, but in a prescribed manner, and it includes quantitative standards for discriminating fish community condition. Judgment is involved in choosing the most appropriate population or community element that is representative of each metric and in setting the scoring criteria. This process can be easily and clearly modified, as opposed to judgments that occur after results are calculated. Each metric is scored against criteria based on expectation developed from appropriate regional reference sites. Metric values approximating, deviating slightly from, or deviating greatly from values occurring at the reference sites are scored as 5, 3, or 1, respectively. The scores of the 12 metrics are added for each station to give an IBI of 60 (excellent) to 12 (very poor). Trophic and tolerance classifications of midwestern and northwestern fish species are listed in Table 1. Additional classifications can be derived from information in State and regional fish texts or by objectively assessing a large statewide database. Use of the IBI in the southern and southwestern United States and its widespread use by water resource agencies may result in further modifications. Past modifications have occurred (Subsection 8.8; Miller et al., 1988a) without changing the IBI's basic theoretical foundations. Sample calculations of the IBI are given in Plafkin et al. (1989).

8.7.6 The steps in calculating the IBI (Figure 1) are explained below:

8.7.6.1 Assign species to trophic guilds; identify and assign species tolerances. Where published data are lacking, assignments are made based on knowledge of closely related species and morphology.

8.7.6.2 Develop scoring criteria for each IBI metric. Maximum species richness (or density) lines are developed from a reference database.

8.7.6.3 Conduct field study and identify fish; note anomalies, eroded fins, poor condition, excessive mucous, fungus, external parasites, reddening, lesions, and tumors. Complete field data sheets (Figure 5).

8.7.6.4 Enumerate and tabulate number of fish species and relative abundances.

8.7.6.5 Summarize site information for each IBI metric.

8.7.6.6 Rate each IBI metric and calculate total IBI score.

8.7.6.7 Translate total IBI score to one of the five integrity classes.

8.7.6.8 Interpret data in the context of the habitat assessment (for a discussion of Integration of Habitat, Water Quality, and Biosurvey data, see Plafkin et al., 1989). Individual metric analysis may be necessary to ascertain specific trends.

8.7.7 The Index of Biotic Integrity (IBI) is based on an integrated analysis of the metrics. However, individual IBI metrics may serve as separate variables to aid in data interpretation. Comparison of commonly-occurring and dominant species are revealing, especially when related to their ecological requirements and tolerances. Larsen et al. (1986) and Rohm et al. (1987) provide examples of such regional characterizations of common and abundant species. The Index of well-being (Iwb), (Gammon, 1980; Hughes and Gammon,

1987) incorporates two abundance and two diversity estimates in approximately equal fashion, thereby representing fish assemblage quality more realistically than a single diversity or abundance measure. The Iwb is calculated as

$$Iwb = 0.5 \ln N + 0.5 \ln B + H'_N + H'_B$$

where N equals the number of individuals caught per kilometer, B equals the biomass of individuals caught per kilometer, and H′ is the Shannon diversity index. Ohio EPA (1987b) and Gammon (1989, personal communication) found that subtracting highly tolerant species from the number and biomass variables, or modified Index of well-being (Iwb), increases sensitivity of the index in degraded environments (Ohio EPA, 1987b; Yoder et al., 1981). The modified Iwb has the same computational formula as the proposed Iwb by Gammon (1976). The main difference is that any of 13 highly tolerant species, exotics, and hybrids are deleted from the numbers and biomass components of the Iwb. The tolerant and exotic species, however, are included in the two Shannon index calculations. This modification eliminated the undesired effect caused by high abundance of tolerant species, but retains the desired influence of the Shannon indices (Ohio EPA, 1987b).

8.7.8 If the size of a particular fish population (e.g., trout or bass species) is of concern, it can be estimated with known confidence limits by several methods. One of the most popular approaches is the removal method (Seber, 1982; Seber and LeCren, 1967; Seber and Whale, 1970). The approach assumes a closed population, equal probability of capture for all fish, and a constant probability of capture from sample to sample (equal sampling effort and conditions). The removal method is applicable to situations in which the total catch is large relative to the total population. If subsequent samples produce equal or greater numbers than previous samples, the population must be resampled. Population size in the two sample cases is estimated by

$$N = C_1^1/(C_1 - C_2)$$

where C_1 and C_2 are the number of fish captured in the first and second samples, respectively. In the three sample cases, population size is estimated by

$$N = \frac{6X^2 - 3XY - Y^2 + 6XY - 3X^2)^{1/2}}{18(X - Y)}$$

where $X = 2C_1 + C_2$, and $Y = C2_1 + C_3$.

8.7.9 Many methods are available to calculate population statistics from removal data including regression, maximum likelihood, and maximum weighted-likelihood. Pubic-domain software is available to assist in calculating these and other fisheries population statistics (Van Deventer and Platts, 1989).

8.8 Description of IBI Metrics

8.8.1 The IBI serves as an integrated analysis because individual metrics may differ in their relative sensitivity to various levels of biological condition. A description and brief rationale for each of the 12 IBI metrics is outlined below. The original metrics described by Karr (1981) for Illinois streams (underlined) are followed by substitutes used in or proposed for different geographic regions and stream sizes. Because of zoogeographic differences, dissimilar families or species are evaluated in different regions, with regional substitutes occupying the same general habitat or niche. The sources for each substitute is footnoted below. Table 2 presents an overview of the IBI metric variations for six areas of the United States and Canada and their sources. Scoring criteria for the 12 original IBI metrics (Karr, 1986) are included in Figure 1).

8.8.2 These metrics assess the species richness component of diversity and the health of the major taxonomic groups and habitat guilds of fishes. Two of the metrics assess community composition in terms of tolerant or intolerant species. Scoring for the first five of these metrics or their substitute metrics requires development of species-waterbody size relationships for different zoogeographic regions. Development of this relationship requires data sufficient to plot the number of species collected from regional reference sites of various stream sizes against a measure of stream size (watershed area, stream order) of those sites. A line is then drawn with slope fit by eye to include 95 percent of the points. Finally the area under the line is trisected into areas that are scored as 5, 3, or 1 (Figure 6). A detailed description of these methods can be found in Fausch et al. (1984), Ohio EPA (1987b), and Karr et al. (1986).

8.8.2.1 Metric 1. Total number of fish species (1,4,5). Substitutes: Total number of native fish species (2,8), and salmonid age classes (6). This number decreases with increased degradation; hybrids and introduced species are not included. In coldwater streams supporting few fish species, the age classes of the species found represent the suitability of the system for spawning and rearing. The number of species is strongly affected by stream size at small stream sites, but not at large river sites (Karr et al., 1986; Ohio EPA, 1987b). Thus, scoring depends on developing species/waterbody size relationships.

8.8.2.2 Metric 2. Number and identity (Page, 1983) of darter species (1). Substitutes: Number and identity of sculpin species (2,4), benthic insectivore species (3,4) salmonid yearlings (individuals) (6); number of sculpins (individuals) (4); percent round-bodied suckers (5), sculpin, and darter species (8). These species are sensitive to degradation resulting from siltation and benthic oxygen depletion because they feed and reproduce in benthic habitats (Kuehne and Barbour, 1983; Ohio EPA, 1987b). Many smaller species live within the rubble interstices, are weak swimmers, and spend their entire lives in an area of 100-400 m^2 (Hill and Grossman, 1987; Matthews, 1986). Darters are appropriate in most Mississippi Basin streams; sculpins and yearling trout occupy the same niche in western streams. Benthic insectivores and sculpins or darters are used in small Atlantic slope streams that have few sculpins or darters and round-bodied suckers are suitable in large midwestern rivers. Scoring requires development of species/waterbody size relationships.

8.8.2.3 Metric 3. Number and identity of sunfish species (1). Substitutes: Number and identity of cyprinid species (2,4), water column species (3,4),

TABLE 2. REGIONAL VARIATIONS OF IBI METRICS[1]

Variations in IBI Metrics	Midwest	New England	Ontario	Central Appalachia	Colorado Front Range	Western Oregon	Sacramento-San Joaquin
1. Total Number of Species	X	X		X	X		X
# native fish species			X			X	
# salmonid age classes[2]						X	X
2. Number of Darter Species	X			X	X		
# sculpin species						X	
# benthic insectivore species		X					
# darter and sculpin species			X				
#salmonid yearlings (individuals)[2]						X	X
% round-bodied suckers	X						
#sculpins (individuals)							X
3. Number of Sunfish Species	X				X		
# cyprinid species						X	
# water column species		X					
# sunfish and trout species			X				
# salmonid species							X
# headwater species	X						

[1]Taken from Karr et al. (1986), Hughes and Gammon (1987), Miller et al. (1988a), Miller et al. (1988b), Ohio EPA (1987b), and Steedman (1988).

[2]Metric suggested by Moyle (1976) or Hughes (1985) as a provisional replacement metric in small western salmonid streams.

[3]An optional metric found to be valuable by Hughes and Gammon (1987).

Note: X = metric used in the region. Many of these variations are applicable elsewhere.

TABLE 2. REGIONAL VARIATIONS OF IBI METRICS (CONTINUED)

Variations in IBI Metrics	Midwest	New England	Ontario	Central Appalachia	Colorado Front Range	Western Oregon	Sacramento-San Joaquin
4. Number of Sucker Species	X	X				X	
# adult trout species[2]						X	X
# minnow species	X				X		
# sucker and catfish species			X				
5. Number of Intolerant Species	X	X			X	X	
# sensitive species	X						
# amphibian species							X
presence of brook trout			X				
6. % Green Sunfish	X						
% common carp						X	
% white sucker		X			X		
% tolerant species	X						
% creek chub				X			
% dace species			X				
7. % Omnivores	X	X	X	X	X	X	
% yearling salmonids[2]						X	X
8. % Insectivorous Cyprinids	X						
% insectivores		X				X	
% specialized insectivores				X	X		
# juvenile trout							X
% insectivorous species	X						

TABLE 2. REGIONAL VARIATIONS OF IBI METRICS (CONTINUED)

Variations in IBI Metrics	Midwest	New England	Ontario	Central Appalachia	Colorado Front Range	Western Oregon	Sacramento-San Joaquin
9. % Top Carnivores	X	X	X				
% catchable salmonids						X	
% catchable wild trout							X
% pioneering species	X						
Density catchable wild trout							X
10. Number of Individuals	X		X	X	X	X	X
Density of individuals		X					
11. % Hybrids	X	X					
% introduced species					X	X	
% simple lithophils	X						
% simple lithophilic species	X						
% native species							X
% native wild individuals							X
12. % Diseased Individuals	X	X	X	X	X	X	
13. Total Fish Biomass[3]						X	

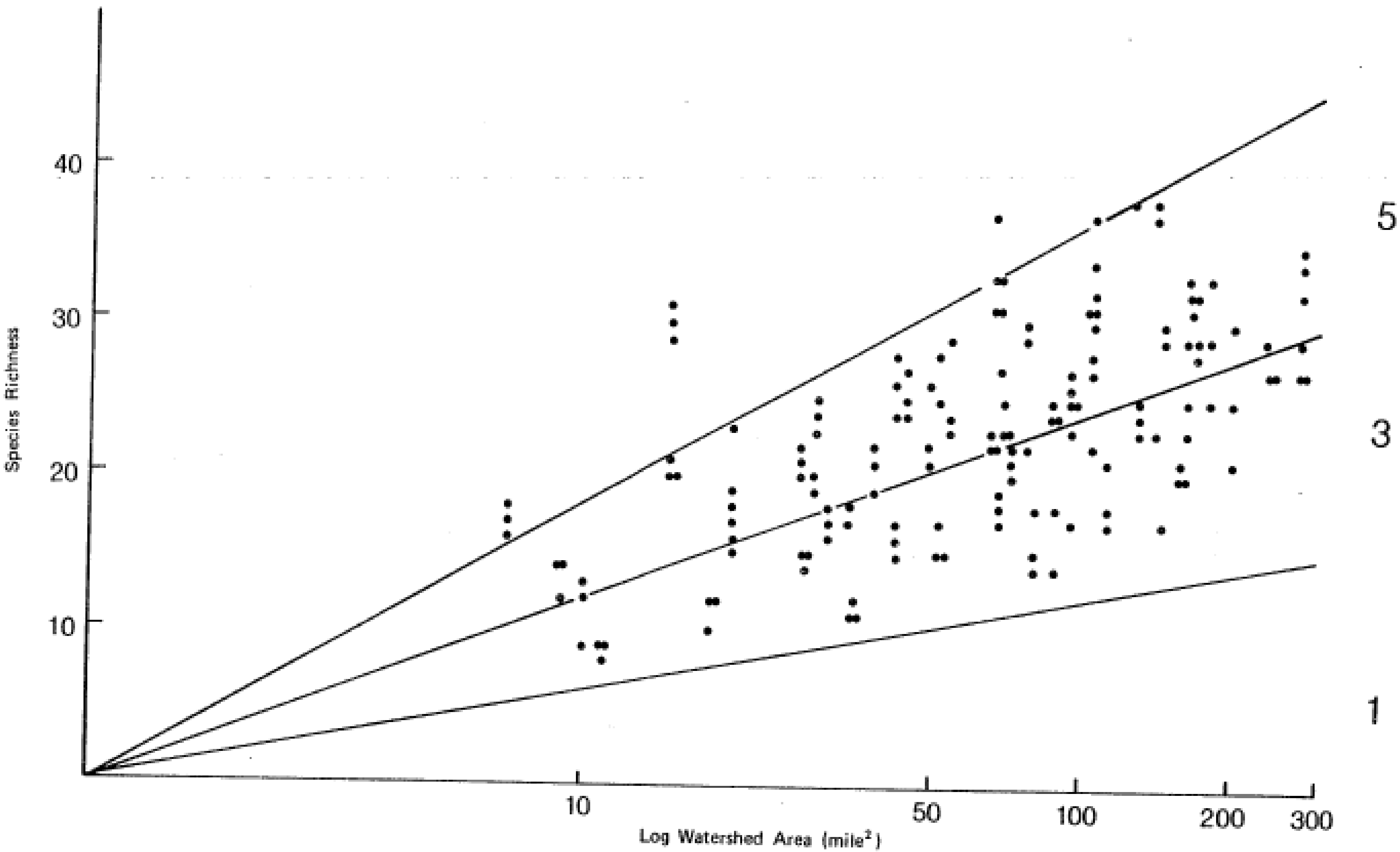

Figure 6. Total number of fish species versus watershed area for Ohio regional reference sites.

salmonid species (4), headwater species (5), and sunfish and trout species (8). These pool species decrease with increased degradation of pools and instream cover (Gammon et al., 1981; Angermeier, 1983; Platts et al., 1983). Most of these fishes feed on drifting and surface invertebrates and are active swimmers. The sunfishes and salmonids are important sport species. The sunfish metric works for most Mississippi Basin streams, but where sunfish are absent or rare, other groups are used. Cyprinid species are used in coolwater western streams; water column species occupy the same niche in northeastern streams; salmonids are suitable in coldwater streams; headwater species serve for midwestern headwater streams and trout and sunfish species are used in southern Ontario streams. Karr et al. (1986) and Ohio EPA (1987b) found the number of sunfish species to be dependent on stream size in small streams, but Ohio EPA (1987b) found no relationship between stream size and sunfish species in medium to large streams, nor between stream size and headwater species in small streams. Scoring of this metric requires development of species/waterbody size relationships.

8.8.2.4 Metric 4. Number and identity of sucker species (1). Substitutes: Number of adult trout species (6), number of minnow species (5); and number of sucker and catfish (8). These species are sensitive to physical and chemical habitat degradation and commonly comprise most of the fish biomass in streams. All but the minnows are long-lived species and provide a multiyear integration of physical/chemical conditions. Suckers are common in medium and large streams; minnows dominate small streams in the Mississippi Basin; and trout occupy the same niche in coldwater streams. The richness of these species is a function of stream size in small and medium sized streams, but not in large rivers. Scoring of this metric requires development of species/waterbody size relationships.

8.8.2.5 Metric 5. Number and identity of intolerant species (1). Substitutes: Number and identity of sensitive species (5), amphibian species (4); and presence of brook trout (8). This metric distinguishes high and moderate quality sites using species that are intolerant of various chemical and physical perturbations. Intolerant species are typically the first species to disappear following disturbance. Species classified as intolerant or sensitive should only represent the 5-10 percent most susceptible species, otherwise this becomes a less discriminating metric. Candidate species are determined by examining regional fishery books for species that were once widespread but have become restricted to only the highest quality streams. Ohio EPA (1987b) uses number of sensitive species (which includes highly intolerant and moderately intolerant species) for head-water sites because highly intolerant species are generally not expected in such habitats. Moyle (1976) suggested using amphibians in northern California streams because of their sensitivity to silvicultural impacts. This also may be a promising metric in appalachian streams which may naturally support few fish species. Steedman (1988) found that the presence of brook trout had the greatest correlation with IBI score in Ontario streams. The number of sensitive and intolerant species increases with stream size in small and medium sized streams but is unaffected by size of large rivers. Scoring of this metric requires development of species/waterbody size relationships.

8.8.2.6 Metric 6. Proportion of tolerant individuals as green sunfish (1). Substitutes: Proportion of individuals as common carp (2,4), white sucker (3,4), tolerant species (5), creek chub (7), and dace (8). This metric is the reverse of Metric 5. It distinguishes low from moderate quality waters. These species show increased distribution or abundance despite the historical degradation of surface waters, and they shift from incidental to dominant in disturbed sites. Green sunfish are appropriate in small Midwestern streams; creek chubs were suggested for central Appalachian streams; common carp were suitable for a coolwater Oregon river; white sucker were selected in the northeast and Colorado where green sunfish are rare to absent; and dace (*Rhinichthys* species) were used in southern Ontario. To avoid weighing the metric on a single species, Karr et al. (1986) and Ohio EPA (1987b) suggest using a small number of highly tolerant species. Scoring of this metric may require development of expectations based on waterbody size.

8.8.3 Trophic Composition Metrics

8.8.3.1 These three metrics assess the quality of the energy base and trophic dynamics of the community. Traditional process studies, such as community production and respiration, are time consuming to conduct and the results are equivocal; distinctly different situations can yield similar results. The trophic composition metrics offer a means to evaluate the shift toward more generalized foraging that typically occurs with increased degradation of the physicochemical habitat.

8.8.3.2 Metric 7. Proportion of individuals as omnivores (1,2,3,4,5,8). Substitutes: Proportion of individuals as yearlings (4).

8.8.3.2.1 The percent of omnivores in the community increases as the physical and chemical habitat deteriorates. Omnivores are defined as species that consistently feed on substantial proportions of plant and animal material. Ohio EPA (1987b) excludes sensitive filter feeding species such as paddlefish and lamprey ammocoetes and opportunistic feeders like channel catfish. Where omnivorous species are nonexistent, such as in trout streams, the proportion of the community composed of yearlings, which initially feed omnivorously, may be substituted.

8.8.3.3 Metric 8. Proportion of individuals which are insectivorous cyprinids (1). Substitutes: Proportion of individuals as insectivore (2,3,5), specialized insectivores (4), and insectivorous species (5);and number of juvenile trout (4).

8.8.3.3.1 Insectivores or invertivores are the dominant trophic guild of most North American surface waters. As the invertebrate food source decreases in abundance and diversity due to physical/chemical habitat deterioration, there is a shift from insectivorous to omnivorous fish species. Generalized insectivores and opportunistic species, such as blacknose dace and creek chub were excluded from this metric by Ohio EPA (1987b). This metric evaluates the midrange of biotic integrity.

8.8.3.4 Metric 9. Proportion of individuals as top carnivores (1,3,8).

Substitutes: Proportion of individuals as catchable salmonids (2), catchable wild trout (4), and pioneering species (5).

8.8.3.4.1 The top carnivore metric discriminates between systems with high and moderate integrity. Top carnivores are species that feed as adults predominantly on fish, other vertebrates, or crayfish. Occasional piscivores, such as creek chub and channel catfish, are not included. In trout streams, where true piscivores are uncommon, the percent of large salmonids is substituted for percent piscivores. These species often represent popular sport fish such as bass, pike, walleye, and trout. Pioneering species are used by Ohio EPA (1987b) in headwater streams typically lacking piscivores.

8.8.4 Fish Abundance and Condition Metrics

8.8.4.1 The last three metrics indirectly evaluate population recruitment, mortality, condition, and abundance. Typically, these parameters vary continuously and are time consuming to estimate accurately. Instead of such direct estimates, the final results of the population parameters are evaluated. Indirect estimation is less variable and much more rapidly determined.

8.8.4.2 Metric 10. Number of individuals in sample (1,2,4,5,8). Substitutes: Density of individuals (3,4).

8.8.4.2.1 This metric evaluates population abundance and varies with region and stream size for small streams. It is expressed as catch per unit effort, either by area, distance, or time sampled. Generally sites with lower integrity support fewer individuals, but in some nutrient-poor regions, enrichment increases the number of individuals. Steedman (1988) addressed this situation by scoring catch per minute of sampling greater than 25 fish as a three, and less than 4 fish as a one. Unusually low numbers generally indicate toxicity, making this metric most useful at the low end of the biological integrity scale. Hughes and Gammon (1987) suggest that in larger streams, where sizes of fish may vary in orders of magnitude, total fish biomass may be an appropriate substitute or additional metric.

8.8.4.3 Metric 11. Proportion of individuals as hybrids (1). Substitutes: Proportion of individuals as introduced species (2,4), simple lithophils (5); and number of simple lithophilic species (5).

8.8.4.3.1 This metric is an estimate of reproductive isolation or the suitability of the habitat for reproduction. Generally as environmental degradation increases, the percent of hybrids and introduced species also increases, but the proportion of simple lithophils decreases. However, minnow hybrids are found in some high quality streams, hybrids are often absent from highly impacted sites, and hybridization is rare and difficult for many to detect. Thus, Ohio EPA (1987b) substitutes simple lithophils for hybrids. Simple lithophils spawn where their eggs can develop in the interstices of sand, gravel, and cobble substrates without parental care. Hughes and Gammon (1987) and Miller et al. (1988a) propose using percent introduced individuals. This metric is a direct measure of the loss of species segregation between midwestern and western fishes that existed before the introduction of midwestern species into western rivers.

8.8.4.4 Metric 12. Proportion of individuals with disease, tumors, fin damage, and skeletal anomalies (1).

8.8.4.4.1 This metric depicts the health and condition of individual fish. These conditions occur infrequently or are absent from minimally impacted reference sites but occur frequently below point sources and in areas where toxic chemicals are concentrated. They are excellent measures of the subacute effects of chemical pollution and the aesthetic value of game and nongame fish.

8.8.4.5 Metric 13. Total fish biomass (optional). Hughes and Gammon (1987) suggest that in larger areas where sizes of fish may vary in orders of magnitude this additional metric may be appropriate.

8.8.4.5.1 Because the IBI is an adaptable index, the choice of metrics and scoring criteria is best developed on a regional basis through use of available publications (Karr et al., 1986; Ohio EPA, 1987b; Miller et al., 1988a). Several steps in the IBI process are common to all regions. The fish species must be listed and assigned to trophic and tolerance guilds. Scoring criteria are developed through use of high quality historical data and data from minimally-impacted regional reference sites. The development of reference sites have been accomplished for much of the country, but continued refinements are expected as more fish community ecology data become available. Once scoring criteria have been established, a fish sample is evaluated by listing the species and their abundances (Figure 5), calculating values for each metric and comparing these values with the scoring criteria. Individual metric scores are added to calculate the total IBI score (Figure 7). Hughes and Gammon (1987) and Miller et al. (1988a) suggest that scores lying at the extremes of scoring criteria can be modified by a plus or minus; a combination of three pluses or three minuses results in a two point increase or decrease in IBI. Ohio EPA (1987b) scores proportional metrics as 1 when the number of species and individuals in samples are fewer than 6 and 75, respectively, when their expectations are of higher numbers.

8.9 Guidance for Use of Field Data Sheets

8.9.1 This subsection provides guidance for use of the bioassessment field and laboratory data sheets. The guidance sheets give brief descriptions of the information required for each data sheet.

8.9.2 Guidance for Header Information (Figure 8)

8.9.2.1 Water body Name: Name of stream or drain.

8.9.2.2 Location: Township, range, section, county where problem area is located. For streams or drains; road crossings or outfall locations should be referenced where applicable.

8.9.3 Reach/Milepoint: Indicate station reach/milepoint.

8.9.4 Latitude/Longitude: Indicate station latitude/longitude.

8.9.5 County/State: Name of county and state where station is located.

8.9.6 Aquatic Ecoregion: Name of ecoregion.

8.9.7 Station: Agency name or number for station.

8.9.8 Investigators: List field personnel involved.

8.9.9 Date: Date of survey.

8.9.10 Agency: Agency name or affiliation (academic, private consulting)

8.9.11 Hydrologic Unit Code: Indicate the USGS cataloging unit number in which the station is located.

8.9.12 Form Completed By: List personnel completing form.

8.9.13 Reason for Survey: The reason why this survey was conducted.

Station No. ______________________

Site ______________________

Metrics[a]	Scoring Criteria[b] 5 (%)	3 (%)	1 (%)	Metric Value	Metric Score
1. Number of Native Fish Species	>67	33-67	<33		
2. Number of Darter or Benthic Species	>67	33-67	<33		
3. Number of Sunfish or Pool Species	>67	33-67	<33		
4. Number of Sucker or Long-Lived Species	>67	33-67	<33		
5. Number of Intolerant Species	>67	33-67	<33		
6. % Green Sunfish or Tolerant Individuals	<10	10-25	>25		
7. % Omnivores	<20	20-45	>45		
8. % Insectivores or Invertivores	>45	20-45	<20		
9. % Top Carnivores	>5	1-5	<1		
10. Total Number of Individuals	>67	33-67	<33		
11. % Hybrids or Exotics	0	0-1	>1		
12. % Anomalies	<1	1-5	>5		

Scorer ______________________ IBI Score __________

Comments: ______________________

(a) Karr's original metrics or commonly used substitutes. See Figure 4 for other possibilities.

(b) Karr's original scoring criteria or commonly used substitutes. These may require refinement in other ecoregions.

Figure 7. Data summary sheet for Fish Bioassessment II.

Waterbody Name ______________________ Location ______________________

Reach/Milepoint ______________________ Latitude/Longitude ______________________

County ____________ State ____________ Aquatic Ecoregion ______________________

Station Number ______________________ Investigators ______________________

Date ____________ Time ____________ Agency ______________________

Hydrologic Unit Code ______________________ Form Completed by ______________________

Reason for Survey ____

____

____

____

Figure 8. Header information used for documentation and identification for sampling stations.

8.10 Guidance for Impairment Assessment Sheet (Figure 4)

8.10.1 Detection of Impairment: Circle the one that applies.

8.10.2 Biological Impairment Indicator: Circle those that apply, as indicated by the benthos, fish, and other aquatic biota.

8.10.3 Brief Description of Problem: Briefly explain the biological nature of the problem, based on field investigation and sampling. List the year and date of previous biological data and reports, and where the information can be found (state file, BIOS).

8.10.4 Cause: Circle those that apply. Indicate which problem appears to be the major cause of the stream impairment.

8.10.5 Estimated Areal Extent of Problem: Record estimated downstream extent of impact (in m) and multiply by approximate stream width (in m) to estimate areal width.

8.10.6 Suspected Source(s) of Problem: Check those that are suspected. Briefly explain why you suspect a specific source, and reference other surveys or studies done to document the problem and its source. Give title of applicable report, author(s) and year published or completed. Use back of sheet if necessary.

8.11 Guidance for Field Collection Data Sheet for Fish Bioassessment II (Figure 5)

8.11.1 Drainage: Give name of stream or river and its basin site descriptor, and unique site code.

8.11.2 Date: Enter day, month, and year of collection.

8.11.3 Sampling Duration: Record length of time in minutes actually collecting fish. If replicates are taken, record them separately.

8.11.4 Sampling Distance: Measure, with a tape or calibrated range finder, the length in meters of reach sampled.

8.11.5 Sampling Area: Multiply the length or reach sampled by the average width sampled. Express in meters squared.

8.11.6 Crew: Indicate crew chief and crew members.

8.11.7 Habitat Complexity/Quality: Circle the descriptor that best describes subjective evaluation of the physicochemical habitat.

8.11.8 Weather: Record air temperature, estimated wind velocity, percent cloud cover, and precipitation.

8.11.9 Flow: Circle most appropriate descriptor.

8.11.10 Information on Gear Used: Specify type, model, and number of electrofisher, or the mesh size and length of seine, or concentration of fish toxicant.

8.11.11 Gear/Crew Performance: Indicate effectiveness of crew in sampling the site. Note problems with equipment, staff, or site obstacles, such as extensive cover, high velocity current, excessive turbidity, floating debris, deep muck or pools, or weather conditions. Electrofishing should be conducted only during normal water flow and clarity conditions. Abnormally turbid conditions are to be avoided as are elevated flow and current because these conditions affect sampling efficiency. Also, if weather conditions are bad (rain or high winds, lightning, etc.), electrofishing should be suspended immediately or at the discretion of field personnel (Ohio EPA, 1990c).

8.11.12 Comments: Record any additional qualitative site data: sketch map or take photographs, note the presence of springs, the evidence of fishing activity, and/or potential or current impacts, the weather conditions (such as evidence of recent high flows or unusually hot or cold weather immediately preceding the survey), the biota observed (insect hatches, potential vertebrate predators, the fish nesting and grazing sites, fish reproductive conditions, or the fish seen but not captured.

8.11.13 Fish (preserved): Indicate if specimens were preserved for permanent collection or further examination.

8.11.14 Number of Individuals; Number of Anomalies: Give total numbers of fish and anomalies for the sample.

8.11.15 Genus/Species: Enter scientific name or unique standard abbreviation for each species captured.

8.11.16 Adults (Number, Weight): Enter the number of adults of each species and their total weight in grams. Individual or batch weight, depending on the species' size and abundance. Species weight can also be determined by weighing a subsample of individuals (20-30 fish spanning the size range collected) and extrapolating for the total number of that species.

8.11.17 Juveniles (Number, Weight): Record the number of juveniles of each species and their total weight as above. Juveniles and adults are distinguished subjectively by coloration and size; the objective is to determine whether both age classes are present.

8.11.18 Anomalies (Number): Indicate the number of fish by individual or species, that are diseased, deformed, damaged, or heavily parasitized. These are determined through careful external examination by a field-trained fish biologist.

8.12 Guidance For Data Summary Sheet for Fish Bioassessment II (Figure 7)

8.12.1 Station Number: Indicate station number.

8.12.2 Station Location: Record brief description of sampling site relative to established landmarks (i.e., roads, bridges).

8.12.3 Metrics: List metrics used to conduct IBI calculations. Use either Karr's original metrics or a published (or well supported) substitute approach. Precede metric selection with analysis of reference site data or a high quality historical database from a representative, large river basin.

8.12.4 Scoring Criteria: List published scoring criteria or use substitutes where necessary. Analyze reference site data or historical data from a representative large river basin before selecting criteria.

8.12.5 Metric Value: Record metric values (number or percent) for the station. Metric values are obtained by comparing the collection data (Figure 5) with the tolerance and trophic guilds previously listed (Table 1). For taxonomic metrics the numbers of different species are added. the total number of individuals is recorded from the field collection data sheet. Proportional metrics are determined by adding the number of individuals in each category and dividing this total by the total number of individuals.

8.12.6 Metric Score: Score each metric by comparing the metric value for the station with the previously chosen scoring criteria. Marginal values can be given a plus or minus (see IBI score below).

8.12.7 Scorer: Enter the scorer's name.

8.12.8 IBI Score: The metric scores (and the pluses and minuses if used) are added to give the IBI score. Three pluses or three minuses may increase or decrease the IBI score by two points.

8.12.9 Comments: Metrics producing contrary results or suggestions for improvement are entered here.

8.13 Habitat Assessment and Physical/Chemical Parameters

8.13.1 An evaluation of habitat quality is critical to any assessment of ecological integrity. The habitat quality evaluation can be accomplished by characterizing selected physical/chemical parameters and by systematic habitat assessment. Through this approach, key parameters can be identified to provide a consistent assessment of habitat quality. This evaluation of habitat quality is relevant to all levels of rapid bioassessment.

8.13.2 Physical Characteristics and Water Quality

8.13.2.1 Both physical characteristics and water quality parameters are pertinent to characterization of the stream habitat. An example of the data sheet used to characterize the physical characteristics and water quality of a site is shown in Figure 9. The information requested includes measurements made routinely during biological surveys. This phase of the survey is broken into two sections: Physical Characterization and Water Quality (Figure 9). These subsections are discussed separately below.

PHYSICAL CHARACTERIZATION/WATER QUALITY
FIELD DATA SHEET

PHYSICAL CHARACTERIZATION

RIPARIAN ZONE/INSTREAM FEATURES

Predominant Surrounding Land Use:

Forest   Field/Pasture   Agricultural   Residential   Commercial   Industrial   Other ______

Local Watershed Erosion: None   Moderate   Heavy

Local Watershed NPS Pollution: No evidence   Some Potential Sources   Obvious Sources

Estimated Stream Width ____ m   Estimated Stream Depth: Riffle ____ m   Run ____ m   Pool ____ m

High Water Mark ____ m   Velocity ____   Dam Present: Yes ___ No ___   Channelized: Yes ___ No ___

Canopy Cover: Open   Partly Open   Partly Shaded   Shaded

SEDIMENT/SUBSTRATE:

Sediment Odors: Normal   Sewage   Petroleum   Chemical   Anaerobic   None   Other ______

Sediment Oils: Absent   Slight   Moderate   Profuse

Sediment Deposits: Sludge   Sawdust   Paper Fiber   Sand   Relict Shells   Other ______

Are the undersides of stones which are not deeply embedded black?   Yes   No

Inorganic Substrate Components

Substrate Type	Diameter	Percent Composition in Sampling Area
Bedrock		
Boulder	>256-mm (10 in.)	
Cobble	64-256-mm (2.5-10 in.)	
Gravel	2-64-mm (0.1-2.5 in.)	
Sand	0.06-2.00-mm (gritty)	
Silt	.004-.06-mm	
Clay	<.004-mm (slick)	

Organic Substrate Components

Substrate Type	Characteristic	Percent Composition in Sampling Area
Detritus	Sticks, Wood, Coarse Plant Materials (CPOM)	
Muck-Mud	Black, Very Fine Organic (FPOM)	
Marl	Grey, Shell Fragments	

WATER QUALITY

Temperature ____ C   Dissolved Oxygen ____   pH ____   Conductivity ____   Other ______

Instrument(s) Used ______

Stream Type: Coldwater   Warmwater

Water Odors: Normal   Sewage   Petroleum   Chemical   None   Other ______

Water Surface Oils: Slick   Sheen   Globs   Flecks   None

Turbidity: Clear   Slightly Turbid   Turbid   Opaque   Water Color ______

WEATHER CONDITIONS

PHOTOGRAPH NUMBER

OBSERVATIONS AND/OR SKETCH

Figure 9. Physical characterization/water quality field data sheet for use with Fish Bioassessment II.

8.13.2.2 Physical Characterization

8.13.2.2.1 Physical characterization parameters include estimations of general land use and physical stream characteristics such as width, depth, flow, and substrate. The evaluation begins with the riparian zone (stream bank and drainage area) and proceeds instream to sediment/substrate descriptions. Such information will provide insight as to what organisms may be present or are expected to be present, and the presence of stream impacts. The information requested in the Physical Characterization section of the Field Data Sheet (Figure 9) is briefly discussed below.

8.13.2.2.2 Predominant Surrounding land Use: Observe the prevalent land-use type in the vicinity (noting any other land uses in the area which, although not predominant, may potentially affect water quality).

8.13.2.2.3 Local Watershed Erosion--The existing or potential detachment of soil within the local watershed (the portion of the watershed that drains directly into the stream) and its movement into a stream is noted. Erosion can be rated through visual observation of the watershed and stream characteristics. (Note any turbidity observed during water quality assessment below.)

8.13.2.2.4 Local Watershed Nonpoint-Source Pollution--This item refers to problems and potential problems other then siltation. Nonpoint source pollution is defined as diffuse agricultural and urban runoff. Other compromising factors in a watershed that may affect water quality or impacts on the stream are feedlots, wetlands, septic systems, dams, and impoundments, and/or mine seepage.

8.13.2.2.5 Estimated Stream Width (m): Estimate the distance from shore to shore at a transect representative of the stream width in the area.

8.13.2.2.6 Estimated Stream Depth (m): riffle, run, and pool. Estimate the vertical distance from water surface to stream bottom at a representative depth at each of the three habitat types.

8.13.2.2.7 High Water Mark (m): Estimate the vertical distance from the stream bank to the peak overflow level, as indicated by debris hanging in bank or floodplain vegetation, and deposition of silt or soil. In instances where bank overflow is rare, a high water mark may not be evident.

8.13.2.2.8 Velocity: Record an estimate of stream velocity in a representative run area.

8.13.2.2.9 Dam Present: Indicate the presence or absence of a dam upstream or downstream of the sampling station. If a dam is present, include specific information relating to alteration of flow.

8.13.2.2.10 Channelized: Indicate whether or not the area around the sampling station is channelized.

8.13.2.2.11 Canopy Cover: Note the general proportion of open to shaded area which best describes the amount of cover at the sampling station.

8.13.2.2.12 Sediment Odors: Disturb sediment and note any odors described (or include any other odors not listed) which are associated with sediment in the area of the sampling station.

8.13.2.2.13 Sediment Oils: Note the term which best describes the relative amount of any sediment oils observed in the sampling area.

8.13.2.2.14 Sediment Deposits: Note those deposits described (or include any other deposit not listed) which are present in the sampling area. Also indicate whether or not the undersides of rocks which are not deeply embedded are black in color (which generally indicates low dissolved oxygen or anaerobic conditions).

8.13.2.2.15 Inorganic Substrate Components: Visually estimate the relative proportion of each of the seven substrate particle types listed that are present in the sampling area.

8.13.2.2.16 Organic Substrate Components: Indicate relative abundance of each of the three substrate types listed.

8.13.2.3 Water Quality

8.13.2.3.1 Information requested in this Subsection (Figure 9) is standard to many aquatic studies and allows for some comparison between sites. Additionally, conditions that may significantly affect aquatic biota are documented. It is important to document recent and current weather conditions because of the potential impact that weather may have on water quality. To complete this phase of the bioassessment, a photograph may be helpful in both identifying station location and documenting habitat conditions. Any observations or data not requested but deemed important by the field observer should be recorded. This section is identical for all protocols and the specific data requested are described below.

8.13.2.3.2 Temperature (^{o}C), Dissolved Oxygen, pH, Conductivity: Measure and record values for each of the water quality parameters indicated, using the appropriate calibrated water quality instrument(s). Note the type of instrument and unit number used.

8.13.2.3.3 Stream Type: Note the appropriate stream designation according to State water quality standards.

8.13.2.3.4 Water Odors: Note those odors described (or include any other odors not listed) that are associated with the water in the sampling area.

8.13.2.3.5 Water Surface Oils: Note the term that best describes the relative amount of any oils present on the water surface.

8.13.2.3.6 Turbidity: Note the term which, based upon visual observation, best describes the amount of material suspended in the water column.

8.13.3 Habitat Quality and Assessment

8.13.3.1 The habitat assessment matrices (Figures 10 and 11) are taken from Barbour and Stribling (1991). The habitat assessment matrix originally published by Plafkin et al (1989) was based on the Stream Classification Guidelines for Wisconsin developed by Ball (1982) and Methods of Evaluating Stream, Riparian, and Biotic Conditions developed by Platts et al. (1983). Also, see Subsection 8.16 for an example of a specific qualitative habitat evaluation index field sheet (Figure 12) constructed for use by Ohio EPA. Because this habitat assessment approach is intended to support biosurvey analysis, the various habitat parameters are weighted to emphasize the most biologically significant parameters. All parameters are evaluated for each station studied. The ratings are then totaled and compared to a reference to provide a final habitat ranking. Scores increase as habitat quality increases. To ensure consistency in the evaluation procedure, descriptions of the physical parameters and relative criteria are included in the rating form.

8.13.3.2 There is a great variability among streams; however, some generalizations concerning similarities among stream types can be made relative to gradient (Barbour and Stribling, 1991). Four generic stream categories using gradient for establishing the framework can be identified: montane, piedmont, valley/plains, and coastal plains. For these four categories, two sets of parameters for assessing habitat quality have been developed. For higher gradient streams there tends to be an increased prevalence of riffles and runs. The matrix for "riffle/run prevalence" was constructed (Barbour and Stribing, 1991) for use in montane and piedmont streams (Figure 10). That for "glide/pool prevalence" (Figure 11) is for use in valley/plains and coastal plains streams.

8.13.3.3 Reference conditions are used to normalize the assessment to the "best attainable" situation. This approach is critical to the assessment because stream characteristics will vary dramatically across different regions. Other habitat assessment approaches may be used; or a more rigorously quantitative approach to measuring the habitat parameters may be used. However, the importance of a holistic habitat assessment to enhance the interpretation of biological data cannot be overemphasized. A more detailed discussion of the relationship between habitat quality and biological condition is presented in Plafkin et al. (1989) and Barbour and Stribling (1991).

8.13.3.4 Habitat parameters (Tabel 3) pertinent to the assessment of habitat quality are separated into three principal categories: primary, secondary, and tertiary. Primary parameters are those that characterize the stream "microscale" habitat and have the greatest direct influence on the structure of the indigenous communities. The primary parameters, which include characterization of the bottom substrate and available cover, estimation of embeddedness, estimation of the flow or velocity and depth regime, and canopy cover have the widest score range (0-20) to reflect their contribution to habitat quality. The secondary parameters measure the "macroscale" habitat such as channel morphology characteristics. These parameters evaluate: channel alteration, bottom scouring and deposition, and pool/riffle, run/bend ratio, and lower bank channel capacity and have a range of 0-15. Tertiary

HABITAT ASSESSMENT FIELD DATA SHEET
RIFFLE/RUN PREVALENCE

Habitat Parameter	Category: Optimal	Sub-Optimal	Marginal	Poor
1. Bottom substrate/ instream cover	Greater than 50% mix of rubble, gravel, submerged logs, undercut banks, or other stable habitat. 16–20	30–50% mix of rubble, gravel, or other stable habitat. Adequate habitat. 11–15	10–30% mix of rubble, gravel, or other stable habitat. Habitat availability less than desirable. 6–10	Less than 10% rubble, gravel, or other stable habitat. Lack of habitat is obvious. 0–5
2. Embeddedness	Gravel, cobble, and boulder particles are between 0–25% surrounded by fine sediment. 16–20	Gravel, cobble, and boulder particles are between 25–50% surrounded by fine sediment. 11–15	Gravel, cobble, and boulder particles are between 50–75% surrounded by fine sediment. 6–10	Gravel, cobble, and boulder particles are over 75% surrounded by fine sediment. 0–5
3. ≤0.15 cms (5 cfs)→ Flow at rep. low	Cold >0.05 cms (2 cfs) Warm >0.15 cms (5 cfs) 16–20	0.03–0.05 cms (1–2 cfs) 0.05–0.15 cms (2–5 cfs) 11–15	0.01–0.03 cms (.5–1 cfs) 0.03–0.05 cms (1–cfs) 6–10	<0.01 cms (.5 cfs) <0.03 cms (1 cfs) 0–5
OR >0.15 cms (5 cfs)→ velocity/depth	Slow (<0.3 m/s), deep (>0.5 m): slow, shallow (<0.5 m); fast (>0.3 m/s), deep; fast, shallow habitats all present. 16–20	Only 3 of the 4 habitat categories present (missing riffles or runs receive lower score than missing pools). 11–15	Only 2 of the 4 habitat categories present (missing riffles or runs receive lower score). 6–10	Dominated by 1 velocity/depth category (usually pools). 0–5
4. Canopy cover (shading)	A mixture of conditions where some areas of water surface fully exposed to sunlight, and other receiving various degrees of filtered light. 16–20	Covered by sparse canopy; entire water surface receiving filtered light. 11–15	Completely covered by dense canopy; water surface completely shaded OR nearly full sunlight reaching water surface. Shading limited to <3 hours per day. 6–10	Lack of canopy, full sunlight reaching water surface. 0–5
5. Channel alteration	Little or no enlargement of islands or point bars, and/or no channelization. 12–15	Some new increase in bar formation, mostly from coarse gravel; and/ or some channelization present. 8–11	Moderate deposition of new gravel, coarse sand on old and new bars; and/or embankments on both banks. 4–7	Heavy deposits of fine material, increased bar development; and/or extensive channelization. 0–3
6. Bottom scouring and deposition	Less than 5% of the bottom affected by scouring and/or deposition. 12–15	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools. 8–11	30–50% affected. Deposits and/or scour at obstructions, constrictions, and bends. Filling of pools prevalent. 4–7	More than 50% of the bottom changing frequently. Pools almost absent due to deposition. Only large rocks in riffle exposed. 0–3
7. Pool/riffle, run/bend ratio (distance between riffles divided by stream width)	Ratio: 5–7. Variety of habitat. Repeat pattern of sequence relatively frequent. 12–15	7–15. Infrequent repeat pattern. Variety of macrohabitat less than optimal. 8–11	15–25. Occasional riffle or bend. Bottom contours provide some habitat. 4–7	>25. Essentially a straight stream. Generally all flat water or shallow riffle. Poor habitat. 0–3
8. Lower bank channel capacity	Overbank (lower) flows rare. Lower bank W/D ratio <7. (Channel width divided by depth or height of lower bank.) 12–15	Overbank (lower) flows occasional. W/D ratio 8–15. 8–11	Overbank (lower) flows common. W/D ratio 15–25. 4–7	Peak flows not contained or contained through channelization. W/D ratio >25. 0–3
9. Upper bank stability	Upper bank stable. No evidence of erosion or bank failure. Side slopes generally <30°. Little potential for future problems. 9–10	Moderately stable. Infrequent, small areas of erosion mostly healed over. Side slopes up to 40° on one bank. Slight potential in extreme floods. 6–8	Moderately unstable. Moderate frequency and size of erosional areas. Side slopes up to 60° on some banks. High erosion potential during extreme high flow. 3–5	Unstable. Many eroded areas. "Raw" areas frequent along straight sections and bends. Side slopes >60° common. 0–2
10. Bank vegetative protection	Over 90% of the streambank surfaces covered by vegetation. 9–10	70–89% of the streambank surfaces covered by vegetation. 6–8	50–79% of the streambank surfaces covered by vegetation. 3–5	Less than 50% of the streambank surfaces covered by vegetation. 0–2
OR Grazing or other disruptive pressure	Vegetative disruption minimal or not evident. Almost all potential plant biomass at present stage of development remains. 9–10	Disruption evident but not affecting community vigor. Vegetative use is moderate, and at least one-half of the potential plant biomass remains. 6–8	Disruption obvious; some patches of bare soil or closely cropped vegetation present. Less than one-half of the potential plant biomass remains. 3–5	Disruption of streambank vegetation is very high. Vegetation has been removed to 2 inches or less in average stubble height. 0–2
11. Streamside cover	Dominant vegetation is shrub. 9–10	Dominant vegetation is of tree form. 6–8	Dominant vegetation is grass or forbes. 3–5	Over 50% of the streambank has no vegetation and dominant material is soil, rock, bridge materials, culverts, or mine tailings. 0–2
12. Riparian vegetative zone width (least buffered side)	>18 meters. 9–10	Between 12 and 18 meters. 6–8	Between 6 and 12 meters. 3–5	<6 meters. 0–2
Column Totals	___	___	___	___

Score ___

Figure 10. Habitat assessment field data sheet, riffle/run prevalence. From Barbour and Stribling (1991).

HABITAT ASSESSMENT FIELD DATA SHEET
GLIDE/POOL PREVALENCE

Habitat Parameter	Category: Optimal	Sub-Optimal	Marginal	Poor
1. Bottom substrate/ instream cover	Greater than 50% mix of rubble, gravel, submerged logs, undercut banks, or other stable habitat. 16–20	30–50% mix of rubble, gravel, or other stable habitat. Adequate habitat. 11–15	10–30% mix of rubble, gravel, or other stable habitat. Habitat availability less than desirable. 6–10	Less than 10% rubble, gravel, or other stable habitat. Lack of habitat is obvious. 0–5
2. Pool substrate characterization	Mixture of substrate materials with gravel and firm sand prevalent; root mats and submerged vegetation common. 16–20	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present. 11–15	All mud or clay or channelized with sand bottom; little or no root mat, no submerged vegetation. 6–10	Hard-pan clay or bedrock; no root mat or vegetation. 0–5
3. Pool variability	Even mix of deep/ shallow/large/small pools present. 16–20	Majority of pools large and deep; very few shallow. 11–15	Shallow pools much more prevalent than deep pools. 6–10	Majority of pools small and shallow or pools absent. 0–5
4. Canopy cover (shading)	A mixture of conditions where some areas of water surface fully exposed to sunlight, and other receiving various degrees of filtered light. 16–20	Covered by sparse canopy; entire water surface receiving filtered light. 11–15	Completely covered by dense canopy; water surface completely shaded OR nearly full sunlight reaching water surface. Shading limited to <3 hours per day. 6–10	Lack of canopy, full sunlight reaching water surface. 0–5
5. Channel alteration	Little or no enlargement of islands or point bars, and/or no channelization. 12–15	Some new increase in bar formation, mostly from coarse gravel; and/ or some channelization present. 8–11	Moderate deposition of new gravel, coarse sand on old and new bars; and/or embankments on both banks. 4–7	Heavy deposits of fine material, increased bar development; and/or extensive channelization. 0–3
6. Deposition	Less than 5% of bottom affected; minor accumulation of coarse sand and pebbles at snags and submerged vegetation. 12–15	5–30% affected; moderate accumulation of sand at snags and submerged vegetation. 8–11	5–30% affected; major deposition of sand at snags and submerged vegetation; pools shallow, heavily silted. 4–7	Channelized; mud, silt, and/or sand in braided or nonbraided channels; pools almost absent due to deposition. 0–3
7. Channel sinuosity	Instream channel length 3 to 4 times straight line distance. 12–15	Instream channel length 2 to 3 times straight line distance. 8–11	Instream channel length 1 to 2 times straight line distance. 4–7	Channel straight; channelized waterway. 0–3
8. Lower bank channel capacity	Overbank (lower) flows rare. Lower bank W/D ratio <7. 12–15	Overbank (lower) flows occasional. W/D ratio 8–15. 8–11	Overbank (lower) flows common. W/D ratio 15–25. 4–7	Peak flows not contained or contained through channelization. W/D ratio >25. 0–3
9. Upper bank stability	Upper bank stable. No evidence of erosion or bank failure. Side slopes generally <30°. Little potential for future problems. 9–10	Moderately stable. Infrequent, small areas of erosion mostly healed over. Side slopes up to 40° on one bank. Slight potential in extreme floods. 6–8	Moderately unstable. Moderate frequency and size of erosional areas. Side slopes up to 60° on some banks. High erosion potential during extreme high flow. 3–5	Unstable. Many eroded areas. "Raw" areas frequent along straight sections and bends. Side slopes >60° common. 0–2
10. Bank vegetative protection	Over 90% of the streambank surfaces covered by vegetation. 9–10	70–89% of the streambank surfaces covered by vegetation. 6–8	50–79% of the streambank surfaces covered by vegetation. 3–5	Less than 50% of the streambank surfaces covered by vegetation. 0–2
OR Grazing or other disruptive pressure	Vegetative disruption minimal or not evident. Almost all potential plant biomass at present stage of development remains. 9–10	Disruption evident but not affecting community vigor. Vegetative use is moderate, and at least one-half of the potential plant biomass remains. 6–8	Disruption obvious; some patches of bare soil or closely cropped vegetation present. Less than one-half of the potential plant biomass remains. 3–5	Disruption of streambank vegetation is very high. Vegetation has been removed to 2 inches or less in average stubble height. 0–2
11. Streamside cover	Dominant vegetation is shrub. 9–10	Dominant vegetation is of tree form. 6–8	Dominant vegetation is grass or forbes. 3–5	Over 50% of the streambank has no vegetation and dominant material is soil, rock, bridge materials, culverts, or mine tailings. 0–2
12. Riparian vegetative zone width (least buffered side)	>18 meters. 9–10	Between 12 and 18 meters. 6–8	Between 6 and 12 meters. 3–5	<6 meters. 0–2
Column Totals	____	____	____	____

Score ______

Figure 11. Habitat assessment field data sheet, glide/pool prevalence. From Barbour and Stribling (1991).

QHEI Score: [ ]

Stream ______ RM ______ Date ______ River Code ______

Location ______ Scorers Name: ______

1] SUBSTRATE (Check *ONLY* Two Substrate *TYPE BOXES; Estimate %* or note every type present);

TYPE	POOL	RIFFLE		POOL	RIFFLE	SUBSTRATE ORIGIN		SUBSTRATE QUALITY
						Check ONE (OR 2 & AVERAGE)		Check ONE (OR 2 & AVERAGE)
☐ ☐-BLDR /SLABS[10]	___	___	☐ ☐-GRAVEL [7]	___	___	☐ -LIMESTONE [1]	SILT:	☐ -SILT HEAVY [-2]
☐ ☐-BOULDER [9]	___	___	☐ ☐-SAND [6]	___	___	☐ -TILLS [1]		☐ -SILT MODERATE [-1]
☐ ☐-COBBLE [8]	___	___	☐ ☐-BEDROCK[5]	___	___	☐ -WETLANDS[0]		☐ -SILT NORMAL [0]
☐ ☐-HARDPAN [4]	___	___	☐ ☐-DETRITUS[3]	___	___	☐ -HARDPAN [0]		☐ -SILT FREE [1]
☐ ☐-MUCK [2]	___	___	☐ ☐-ARTIFICIAL[0]	___	___	☐ -SANDSTONE [0]	EMBEDDED	☐ -EXTENSIVE [-2]
☐ ☐-SILT [2]	___					☐ -RIP/RAP [0]	NESS:	☐ -MODERATE [-1]
						☐ -LACUSTRINE [0]		☐ -NORMAL [0]
						☐ -SHALE [-1]		☐ -NONE [1]
						☐-COAL FINES [-2]		

NOTE: (Ignore sludge that originates from point-sources; score on natural substrates)

NUMBER OF SUBSTRATE TYPES: ☐-5 or More [2] ☐-4 or Less [0]

COMMENTS ______

Substrate [ ] Max 20

2] INSTREAM COVER

TYPE: (Check *All* That Apply)

☐ -UNDERCUT BANKS [1]	☐ -DEEP POOLS> 70 cm [2]	☐ -OXBOWS [1]
☐ -OVERHANGING VEGETATION [1]	☐ -ROOTWADS [1]	☐ -AQUATIC MACROPHYTES [1]
☐ -SHALLOWS (IN SLOW WATER) [1]	☐ -BOULDERS [1]	☐ -LOGS OR WOODY DEBRIS [1]
☐ -ROOTMATS [1]		

COMMENTS: ______

AMOUNT: (Check *ONLY* One or check 2 and *AVERAGE*)

☐ - EXTENSIVE > 75% [11]
☐ - MODERATE 25-75% [7]
☐ - SPARSE 5-25% [3]
☐ - NEARLY ABSENT < 5%[1]

Cover [ ] Max 20

3] CHANNEL MORPHOLOGY: (Check *ONLY* One PER Category OR check 2 and *AVERAGE*)

SINUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY	MODIFICATIONS/OTHER	
☐ - HIGH [4]	☐ - EXCELLENT [7]	☐ - NONE [6]	☐ - HIGH [3]	☐ - SNAGGING	☐ - IMPOUND.
☐ - MODERATE [3]	☐ - GOOD [5]	☐ - RECOVERED [4]	☐ - MODERATE [2]	☐ - RELOCATION	☐ - ISLANDS
☐ - LOW [2]	☐ - FAIR [3]	☐ - RECOVERING [3]	☐ - LOW [1]	☐ - CANOPY REMOVAL	☐ - LEVEED
☐ - NONE [1]	☐ - POOR [1]	☐ - RECENT OR NO RECOVERY [1]		☐ - DREDGING	☐ - BANK SHAPING
				☐ - ONE SIDE CHANNEL MODIFICATIONS	

COMMENTS: ______

Channel [ ] Max 20

4]. RIPARIAN ZONE AND BANK EROSION - (check ONE box per bank or check 2 and AVERAGE per bank) ★River Right Looking Downstream★

RIPARIAN WIDTH	FLOOD PLAIN QUALITY (*PAST 100 FOOT RIPARIAN*)		BANK EROSION
L R (Per Bank)	L R (Most Predominant Per Bank)	L R	L R (Per Bank)
☐ ☐ -WIDE > 50m [4]	☐ ☐-FOREST, SWAMP [3]	☐ ☐-CONSERVATION TILLAGE [1]	☐ ☐ -NONE/LITTLE [3]
☐ ☐ - MODERATE 10-50m [3]	☐ ☐-SHRUB OR OLD FIELD [2]	☐ ☐ -URBAN OR INDUSTRIAL [0]	☐ ☐ -MODERATE [2]
☐ ☐ -NARROW 5-10 m [2]	☐ ☐-RESIDENTIAL,PARK,NEW FIELD [1]	☐ ☐ -OPEN PASTURE,ROWCROP [0]	☐ ☐ -HEAVY/SEVERE[1]
☐ ☐ - VERY NARROW <5 m[1]	☐ ☐ -FENCED PASTURE [1]	☐ ☐ -MINING/CONSTRUCTION [0]	
☐ ☐ - NONE [0]			

COMMENTS: ______

Riparian [ ] Max 10

5.]POOL/GLIDE AND RIFFLE/RUN QUALITY

MAX. DEPTH	MORPHOLOGY	CURRENT VELOCITY [POOL & RIFFLES!]	
(Check 1 ONLY!)	(Check 1 or 2 & AVERAGE)	(Check *All* That Apply)	
☐ - >1m [6]	☐ -POOL WIDTH > RIFFLE WIDTH [2]	☐ -EDDIES[1]	☐ -TORRENTIAL[-1]
☐ - 0.7-1m [4]	☐ -POOL WIDTH = RIFFLE WIDTH [1]	☐ -FAST[1]	☐ -INTERSTITIAL[-1]
☐ - 0.4-0.7m [2]	☐ -POOL WIDTH < RIFFLE W. [0]	☐ -MODERATE [1]	☐ -INTERMITTENT[-2]
☐ - 0.2- 0.4m [1]		☐ -SLOW [1]	
☐ - < 0.2m [POOL=0]			

COMMENTS: ______

Pool/Glide [ ] Max 12

CHECK ONE OR CHECK 2 AND AVERAGE

RIFFLE /RUN DEPTH	RIFFLE/RUN SUBSTRATE	RIFFLE/RUN EMBEDDEDNESS
☐ - GENERALLY >10 cm;MAX > 50 [4]	☐-STABLE (e.g.,Cobble, Boulder) [2]	☐ - NONE [2]
☐ - GENERALLY >10 cm; MAX < 50[3]	☐-MOD. STABLE (e.g.,Large Gravel) [1]	☐ - LOW [1]
☐ - GENERALLY 5-10 cm[1]	☐-UNSTABLE (Fine Gravel,Sand) [0]	☐ - MODERATE [0]
☐ - GENERALLY < 5 cm [RIFFLE=0]		☐ - EXTENSIVE [-1]

COMMENTS: ______

☐ - NO RIFFLE [Metric=0]

Riffle/Run [ ] Max 8

Gradient [ ] Max 10

6] GRADIENT (ft/mi): ______ DRAINAGE AREA (sq.mi.): ______

%POOL: [ ] %GLIDE: [ ]
%RIFFLE: [ ] %RUN: [ ]

Figure 12. Example of Ohio EPA (1991) qualitative habitat evaluation index field sheet.

Is Sampling Reach Representative of Stream? (Y/N)____ If Not, Explain:

Additional Comments/Pollution Impacts:

	Gear	Distance	Water Clarity	Water Stage
First Sampling Pass:				
Second Sampling Pass:				
Third-Sampling Pass:				

Subjective Rating (1-10)

Aesthetic Rating (1-10)

CANOPY (% OPEN) ________ GRADIENT: ☐-LOW ☐-MODERATE ☐-HIGH PHOTOS: ________

STREAM MEASUREMENTS: AVERAGE WIDTH: ______ AVERAGE DEPTH: ______ MAXIMUM DEPTH: ______

DRAWING OF STREAM:

FLOW⇨

Figure 12. Example of Ohio EPA (1991) qualitative habitat evaluation index field sheet (continued).

parameters evaluate riparian and bank structure and comprise four parameters: upper bank stability, bank vegetative stability, streamside cover, and width of riparian vegetative zone. These tertiary parameters are most often ignored in biosurveys. The tertiary parameters have a score range of 0-10.

8.13.3.5 Habitat evaluations (Table 3) are first made on instream habitat, followed by channel morphology, and finally on structural features of the bank and riparian vegetation. Stream segment length or area assessed will vary with each site. Generally, primary parameters are evaluated within the first riffle/pool sequence, or the immediate sampling area such as in the case of fish sampling. Secondary and tertiary parameters are evaluated over a larger stream area, primarily in an upstream direction where conditions will have the greater impact on the community being studied. The actual habitat assessment process involves rating each of the nine parameters as either: excellent, good, fair, or poor based on the criteria included on the Habitat Assessment Field Data Sheet (Figures 10 and 11).

8.13.3.6 A total habitat score is obtained for each biological station and compared to a site-specific control or regional reference station. The ratio between the score for the station of interest and the score for the control or regional reference provides a percent comparability measure for each station Table 3). The station is then classified on the basis of its similarity to expected conditions (as represented by the control or reference station), and its inferred potential to support an acceptable level of biological comminity health.

8.13.3.7 The use of a percent comparability evaluation (Table 3) allows for regional and stream-size differences which affect flow or velocity, substrate, and channel morphology. Some regions are characterized by streams having a lower channel gradient. Such streams are typically shallower, have a greater pool/riffle or run/bend ratio, and less stable substrate than streams with a steep channel gradient. Although some low gradient streams do not provide the diversity of habitat or fauna afforded by steeper gradient streams, they are characteristic of certain regions. Use of the matrix presented as Figure 14 can allow more direct evaluation of low gradient streams relative to regional expectations.

8.13.3.8 Listed below is a general explanation for each of the twelve habitat parameters to be evaluated for riffle/run prevalent streams (higher gradient, Figure 10).

8.13.3.9 Primary Parameters-Substrate and Instream Cover

8.13.3.9.1 The primary instream habitat characteristics directly pertinent to the support of aquatic communities consist of substrate type and stability, availability of refugia, and migration/passage potential. These primary habitat parameters are weighted with the highest weighting reflective of their degree of importance to the biological communities.

1. Bottom Substrate/Instream Cover--This refers to the availability of habitat for support ofaquatic organisms. A variety of substrate materials and habitat types is desirable. The presence of rock and gravel in flowing

TABLE 3. NINE HABITAT PARAMETERS AND ASSESSMENT CATEGORY

Condition/Parameter	Condition			
	Excellent	Good	Fair	Poor
PRIMARY-SUBSTRATE AND INSTREAM COVER				
1. Bottom substrate/instream cover	16-20	11-15	6-10	0-5
2. Embeddedness	16-20	11-15	6-10	0-5
3. Flow/velocity/depth	16-20	11-15	6-10	0-5
4. Canopy cover (shading)	16-20	11-15	6-10	0-5
SECONDARY-CHANNEL MORPHOLOGY				
5. Channel alteration	12-15	8-11	4-7	0-3
6. Bottom scouring and deposition	12-15	8-11	4-7	0-3
7. Pool/riffle, run/bend ratio	12-15	8-11	4-7	0-3
8. Lower bank channel capacity	12-15	8-11	4-7	0-3
TERTIARY-RIPARIAN AND BANK STRUCTURE				
9. Upper Bank stability	9-10	6-8	3-5	0-2
10. Bank vegetative stability (grazing/ disruptive pressure)	9-10	6-8	3-5	0-2
11. Streamside cover	9-10	6-8	3-5	0-2
12. Riparian vegetative zone width	9-10	6-8	3-5	0-2

Assessment Category	Percent of Comparability
Comparable to Reference	≥90%
Supporting	75-89%
Partially Supporting	60-74%
Non-Supporting	≤59%

streams is generally considered the most desirable habitat. However, other forms of habitat may provide the niches required for community support. For example, logs, tree roots, submerged or emergent vegetation, undercut banks, etc., will provide excellent habitat for a variety of organisms, particularly fish. Bottom substrate is evaluated and rated by observation.

2. Embeddedness--The degree to which boulders, rubble, or gravel are surrounded by fine sediment indicates suitability of the stream substrate as habitat for benthic macroinvertebrates and for fish spawning and egg incubation. Embeddedness is evaluated by visual observation of the degree to which larger particles are surrounded by sediment. In some western areas of the United States, embeddedness is regarded as the stability of cobble substrate by measuring the depth of burial of large particles (cobble, boulders).

3. Stream Flow and/or Stream Velocity--Stream flow relates to the ability of a stream to provide and maintain a stable aquatic environment. Stream flow (water quantity and gradient) is most critical to the support of aquatic communities when the representative low flow is $\leq$0.15 cms (5 cfs). In these small streams, flow should be estimated in a straight stretch of run area where banks are parallel and bottom contour is relatively flat. Even where a few stations may have flows in excess of 0.15 cms, flow may still be the predominate constraint. Therefore, the evaluation is based on flow rather than velocity.

4. Canopy Cover (Shading)--Shading, as provided by canopy cover, is important for the control of water temperature, its effect on biological processes in general, and as a factor in photosynthetic activity and primary production. A diversity of shade conditions is considered optimal, that is, with some areas of the sampling station receiving direct sunlight, others, complete shade, and other, filtered light.

8.13.3.10 In larger streams and rivers (> 0. 15 cms), velocity, in conjunction with depth, has a more direct influence than flow on the structure of benthic communities (Osborne and Hendricks, 1983) and fish communities (Oswood and Barber, 1982). The quality of the aquatic habitat can, therefore, be evaluated in terms of a velocity, and depth relationship. As patterned after Oswood and Barber (1982), four general categories of velocity and depth are optimal for benthic and fish communities: (1) slow (<0.3 m/s), shallow (<0.5 m); (2) slow (<0.3 m/s), deep (>0.5 m); (3) fast (>0.3 m/s), deep (>0.5 m); and (4) fast (>0.3 m/s), shallow (<0.5 m). Habitat quality is reduced in the absence of one or more of these four categories.

8.13.3.11 Secondary Parameters-Channel Morphology

8.13.3.11.1 Channel morphology is determined by the flow regime of the stream, local geology, land surface form, soil, and human activities (Platts et al. 1983). The sediment movement along the channel, as influenced by the tractive forces of flowing water and the sinuosity of the channel, also affects habitat conditions.

5. Channel Alteration--The character of sediment deposit from upstream is an indication of the severity of watershed and bank erosion and stability of the stream system. The growth or appearance of sediment bars tends to increase in depth and length with continued watershed disturbance. Channel alteration also results in deposition, which may occur on the inside of bends, below channel constrictions, and where stream gradient flattens out. Channelization (e.g., straightening, construction of concrete embankments) decreases stream sinuosity, thereby increasing stream velocity and the potential for scouring.

6. Bottom Scouring and Deposition--These parameters relate to the destruction of instream habitat resulting from the problems described above. Characteristics to observe are scoured substrate and degree of siltation in pools and riffles. Scouring result from high velocity flows. The potential for scouring is increased by channelization. Deposition and scouring result from the transport of sediment or other particulates and may be an indication of large scale watershed erosion. Deposition and scouring is rated by estimating the percentage of an evaluated reach that is scoured or silted (i.e., 50-ft silted in a 100-ft stream length equals 50 percent).

7. Pool/Riffle, Run/Bend Ratio--These parameters assume that a stream with riffles or bends provides more diverse habitat than a straight (run) or uniform depth stream. Bends are included because low gradient streams may not have riffle areas, but excellent habitat can be provided by the cutting action of water at bends. The ratio is calculated by dividing the average distance between riffles or bends by the average stream width. If a stream contains riffles and bends, the dominant feature with the best habitat should be used.

8. Lower bank channel capacity--This parameter is designed to allow evaluation of the ability of a stream channel to contain normal peak flows. since the lower bank is that over which water initially escapes, it is the focus of this individual parameter.

8.13.3.12 Tertiary Parameters-Riparian and Bank Structure

8.13.3.12.1 Well-vegetated banks are usually stable regardless of bank undercutting; undercutting actually provides excellent cover for fish (Platts et al., 1983). The ability of vegetation and other materials on the streambanks to prevent or inhibit erosion is an important determinant of the stability of the stream channel and instream habitat for indigenous organisms. Because riparian and bank structure indirectly affect the instream habitat features, they are weighted less than the primary or secondary parameters.

8.13.3.12.2 Tertiary parameters are evaluated by observation of both upper and lower bank characteristics. The upper bank is the land area from the break in the general slope of the surrounding land to the normal high water line. The upper bank is normally vegetated and covered by water only during extreme high water conditions. Land forms vary from wide, flat floodplains to narrow, steep slopes. The lower bank is the intermittently submerged portion of the stream cross section from the normal high water line to the lower water line. The lower channel defines the stream width.

9. Upper Bank Stability--Bank stability is rated by observing existing or potential detachment of soil from the upper and lower stream bank and its potential movement into the stream. Steeper banks are generally more susceptible to erosion and failure, and may not support stable vegetation. Streams with poor banks will often have poor instream habitat. Adjustments should be made in areas with clay banks where steep, bare areas may not be as susceptible to erosion as other soil types.

10. Bank Vegetative Stability (Grazing/Disruptive Pressure)--Vegetative stability is evaluated here as it relates to reduction of erosion and biological contribution to the aquatic ecosystem. Bank soil is generally held in place by plant root systems. Erosional protection may also be provided by boulder, cobble, or gravel material. Areas of higher vegetative coverage receive higher ratings (Ball, 1982; Platts et al., 1983). An estimate of the density of bank vegetation (or proportion of boulder, cobble, or gravel material) covering the bank provides an indication of bank stability and potential instream sedimentation. Vegetative stability is best rated in areas of little riparian zone disturbance. Areas exposed to grazing pressures or other disruption should be evaluated under the second set of conditions. Grazing or other disruptive pressure is evaluated in terms of the potential plant biomass at the site in any given season.

11. Streamside Cover--Streamside cover vegetation is evaluated in terms of provision of stream-shading; and escape cover or refuge for fish. A rating is obtained by visually determining the dominant vegetation type covering the exposed stream bottom, bank, and top of bank. Platts (1974) found that streamside cover consisting primarily of shrub had a higher fish standing crop than similar-size streams having tree or grass streamside cover. Riparian vegetation dominated by shrubs and trees provides the course particulate organic matter (CPOM) source in allochthonous systems.

12. Riparian Vegetative Zone Width (Least Buffered Side)--The riparian buffer zone is rated by its width on the side with the nearest disturbance or human influence. Increasing buffer zone width is positively correlated with shade. Vegetated buffer zones are also effective in removal of particulate pollutants from storm runoff, can reduce runoff velocity and volume, and can aid in the recharging of groundwater.

8.13.3.12 The matrix constructed for lower gradient streams likely to be encountered is coastal plains and prairie regions (Figure 11; Barbour and Stribing, 1991) differs from Figure 10 by two parameters. The following two parameters (numbers 2 and 3) have been added to emphasize the increased importance of pools as habitat in these streams.

2. Pool Substrate Characterization--diversity and variability in substrate

particle size are rated higher than uniform particle sizes in pool substrates.

3. Pool Variability--This parameter rates the mixture of pool sizes within a stream reach. Variability in pool sizes will support a healthy fisheries and a more diverse benthic macroinvertebrate assemblage.

8.13.3.13 Additional Habitat Assessment Considerations

8.13.3.13.1 Two additional variables are important and should be considered by the investigator: (1) seasonal aspects of habitat evaluation; and (2) the length of the stream reach to be evaluated for habitat quality. To properly address both of these considerations, the major objective of the habitat assessment should be identified. If the habitat assessment is being conducted in relation to the biological collections, all field assessments and collections should be performed concurrently, and the sampling domain (site boundaries) should be critically established. On the other hand, if the purpose of the habitat assessment is to characterize or classify a stream or watershed, a different sampling regime or criterion might be established.

8.13.13.2 With regard to seasonality, it is important to understand that the habitat quality may change depending on the time of the assessment. However, the primary habitat parameters amy change most dramatically, having the greatest influence on the communities under study. This particular habitat assessment approach is designed as a tool for evaluating the potential biological condition of the communities. With this in mind, the actual sampling site where the resident communities are being collected is of central importance in the habitat evaluation. The sampling site should be evaluated for the primary habitat parameters.

8.13.13.3 The stream reach upstream of the site should be included in the evaluation of the secondary and tertiary parameters. The actual delineation of the length of the reach will depend on the objectives of the study. For nonpoint source assessment, the reach may be much as a half mile; for point source evaluations, the reach may be only a few hundred yards. In the assessment of the fish community, a downstream reach amy be incorporated onto the habitat evaluation for the primary and secondary parameters.

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8.15 Agencies Currently Using or Evaluating Use of the IBI and Iwb for Water Quality Investigations

1. Alabama Geological Survey

2. Illinois Environmental Protection Agency

3. Iowa Conservation Commission

4. Kansas Department of Wildlife and Parks

5. Kansas Department of Health and Environment

6. Kentucky Cabinet for Natural Resources and Environmental Protection

7. Nebraska Department of Environmental Control

8. North Carolina Division of Environmental Management

9. Ohio Environmental Protection Agency

10. Oklahoma State Department of Health

11. Tennessee Valley Authority

12. U.S. EPA Region I

13. U.S. EPA Region II

14. U.S. EPA Region V

15. Vermont Department of Environmental Conservation

16. Wisconsin Department of Natural Resources

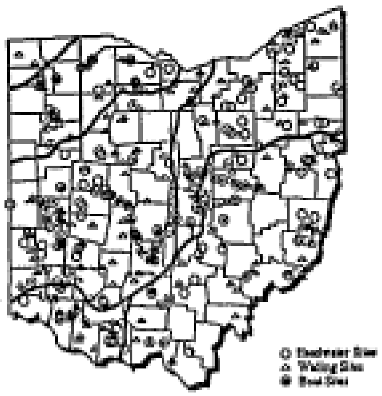
17. Indiana Department of Environmental Management

18. Arizona Department of Game and Fish

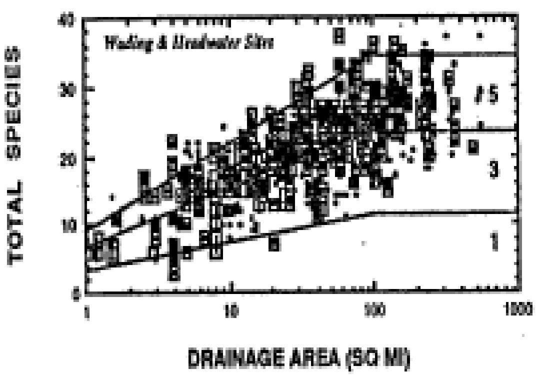
8.16 Ohio EPA Fish Index of Biotic Integrity (IBI), Modified Index of Well-Being (Iwb), and Qualitative Habitat Evaluation Index (QHEI)

8.16.1 The principal methods for determining the overall fish community health and well-being used by the Ohio EPA are the Index of Well-Being (Iwb) developed by Gammon (1976), and modified by Ohio EPA (see Ohio EPA, 1987b, 1991), the Index of Biotic Integrity (IBI) developed by Karr (1981), and the qualitative habitat evaluation index (QHEI) developed by Rankin (1989). The Iwb is based on structural attributes of the fish community, and the IBI incorporates functional characteristics. The fish technique used by Ohio EPA to obtain fish relative abundance and distribution data is pulsed direct current (D.C.) electrofishing. Depending on the type of habitat sampled, six sampling methods currently being used are: (1) boat-mounted electrofishing - straight electrode array (2) boat-mounted electrofishing - circular electrode array, (3) boat longline - riffle method; (4) Sportyak generator unit (5) longline generator unit, and (6) Backpack electrofishing - battery unit. Fish data collected with these devices are used for the purpose of calculating the Index of Biotic Integrity (IBI) and Modified Index of Well-Being (Iwb) scores from which aquatic life use attainment and water quality are determined. Figure 13 is a flowchart of the biosurvey approach for fish bioassessment used

I. Reference Sites - Select & Sample



II. Calibrate multi-metric indices (IBI, ICI)

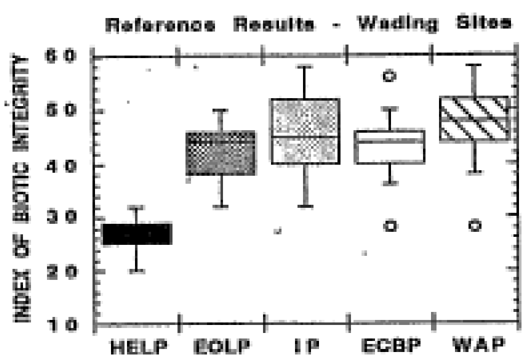


III. Fully calibrated index - differentiate site types for fish; statewide for invertebrates.

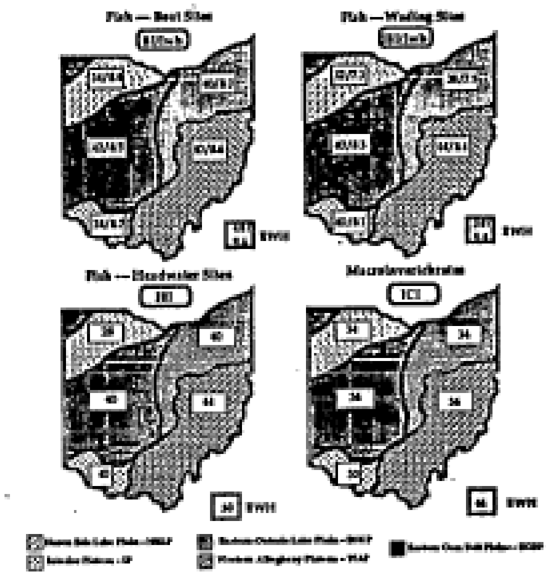
IBI - calibrated for use in Ohio for Wading Sites.

Category	IBI Metric	Metric Score 5	3	1
	# of Species	Varies with drainage area		
Species	# of Darters	Varies with drainage area		
Comp-	# of Sunfish	>3	2-3	<2
osition	# of Suckers	Varies with drainage area		
	# of Intolerants			
	<100 Sq. Mi.	>5	3-5	<3
	>100 Sq. Mi.	Varies with drainage area		
	% Tolerants	Varies with drainage area		
Trophic	% Omnivores	>19	19-34	>34
Comp-	% Insectivores			
osition	<30 Sq. Mi.	Varies with drainage area		
	>30 Sq. Mi.	>55	26-55	<26
	% Top Carnivores	>5	1-5	<1
Fish	# of Individuals	>750	200-750	<200
Condition	% Simple Litho.	>36	18-36	<18
	% DELTs	<0.1	0.1-1.3	<200

IV. Evaluate reference site score distribution-examine for ecoregion differences.



V. Derive numerical biocriteria for each aquatic life use designation as defined in the Ohio WQS.



VI. Use biocriteria in ambient assessments.

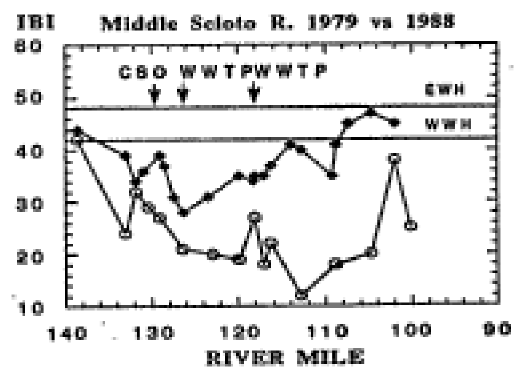


Figure 13. Flowchart of biosurvey approach for fish bioassessment used by Ohio EPA (1991).

by Ohio EPA. Figure 14 is an example of a fish data sheet constructed for immediate entry into a computer data base.

8.16.2 Ohio EPA (1989) also collects data for a general qualitative habitat evaluation (Figure 12) for calculating the Qualitative Habitat Evaluation Index (QHEI) developed by Rankin (1989). The QHEI is designed to provide an empirical, quantified evaluation of the general lotic macrohabitat characteristics that are important to fish communities. A detailed analysis of the development and use of the QHEI is found in Rankin (1989).

8.16.3 For details of specific Ohio EPA field and laboratory methods for fish bioassessment (e.g., sampling site selection, fish sampling procedures, field counting and weighing procedures, handling preserved specimens, data handling and analysis), one should consult Ohio EPA (1987a, 1987b, 1989, 1990b).

Fish Data Sheet

Field Crew: Collector/Recorder ____________ Time of Day: ______ Page ___ of ___

River/Stream: ____________ Location: ____________

Date: ____________

River Code: ______ Sampler Type: ____ Time Fished: '___" ___ Total Seconds ______

RM: ______ Depth: ______ Observed Flow: ______

Distance: ______ Data Source: ______ Number of Species: ______

Anomalies: A-anchor worm; B-black spot; C-leeches; D-deformities; E-eroded fins, F-fungus; L-lesions; M-multiple DELT anomalies, N-blind, P-parasites; Y-popeye; S-emaciated; W-swirled scales; T-tumors; Z-other/. [H-Heavy; L-Light are combined with anomalies A, B, and C]

SPECIES	# WEIGHED	TOTAL COUNTED	WEIGHT (GRAMS)	ANOMALIES

Mass Weighing Convention: Total Weight (g) — 536 (12) — Number Weighed

Figure 14. Example of Ohio EPA (1991) field data sheet constructed for immediate entry into a computer data base.

Page ____ of _____

Anomalies: A-anchor worm; B-black spot; C-leeches; D-deformities; E-eroded fins, F-fungus; L-lesions; M-multiple DELT anomalies, N-blind, P-parasites; Y-popeye; S-emaciated; W-swirled scales; T-tumors; Z-other/. [H-Heavy; L-Light are combined with anomalies A, B, and C]

SPECIES	# WEIGHED	TOTAL COUNTED	WEIGHT (GRAMS)	ANOMALIES

Mass Weighing Convention: Total Weight (g) 536 12 Number Weighed

Figure 14. Example of Ohio EPA (1991) field data sheet constructed for immediate entry into a computer data base (continued).

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